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Contents

Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

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x the first digit:

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y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

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Introduction

A Study Item on RAN aspects of Machine-Type and other Mobile Data Applications Communications Enhancements has been approved by the RAN#59 plenary in Vienna. This report captures the output of the study.

1 Scope

The present document constitutes the output of the "RAN aspects of Machine-Type and other Mobile Data Applications Communications Enhancements" (FS_MTCe_RAN) study. The TR captures RAN view on the possible solutions identified during the study and the conclusions and recommendations for further work.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] RP-130396: "RAN aspects of Machine-Type and other Mobile Data Applications Communications Enhancements" SID.

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

<example>: <text used to clarify abstract rules by applying them literally>.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

<symbol> <Explanation>

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

SDDTE Small Data and Device Triggering Enhancements
UEPCOP UE Power Consumption Optimizations

4 General

This Technical Report investigates and evaluates the RAN-impacting solutions that have been proposed by SA2 to address the objectives outlined in the SDDTE and UEPCOP Building Blocks of the SA2 work item on Machine Type and other mobile data applications Communications Enhancements. More in general the report identifies and evaluates mechanisms that enhance the ability of the RAN to handle traffic profiles comprising small data transfers generated by both machine-type and non-machine-type devices and applications.

Enhancements in the following areas are investigated in the context of improving both signalling efficiency and UE power consumption in the presence of traffic involving small data transfers (with inter-arrival time from several seconds to many hours):

- Signalling Overhead Reduction:
    - Improved RRC connection management (establishment, reestablishment, release) as well as potential mechanisms to support short-lived connections or connectionless approaches
    - Improved handling of small data during connected mode
    - Associated radio and network (S1AP/RANAP) control plane signalling optimisations for the above procedures
- UE Power Consumption:
    - Solutions to lower UE power consumption (as per the service requirements defined clause in clause 7.1.1 of TS 22.368 and clause 4.3.1 of TS 22.101).

5 Solutions for Signalling Overhead Reduction

5.1 Optimized RRC connection management

5.1.1 Solution 1a. Signalling reduction by RRC message combining

NOTE: This solution is described in TR 23.887 v0.9.0, section 5.1.1.3.7 "Service Request signalling reduction by RRC message combining".

The proposed solution reduces the number of RRC messages by combining the information exchanged between the UE and the network into fewer RRC messages. The solution is proposed for both LTE and UMTS.

5.1.1.1 RAN aspects

Table 5.1.1.1-1: Qualitative analysis for Solution 1a

Applicability	Applicable for both MT and MO cases. It allows the transmission of a single packet (pair) or multiple (UL/DL) packets Likely applicable to RRC Connection Setup procedure in general (i.e. irrespective of small data applications)
Impacts to radio protocols	There would be significant impact on RRC procedures for combining RRC connection establishment, DRB setup, SMC. Service Request has to be added to RRC Connection Request. RRC Connection Setup has to contain SRB1 and DRB configuration and AS security parameters. Normally, DRB configuration is encrypted, so some IEs in this message need to be partially encrypted. Since partial encryption is foreseen, there will be impact to PDCP layer. The size limitation of RRC connection request should be considered. For LTE, increasing the size of Msg3 beyond the current limits may impact the MAC layer. The eNB cannot know in advance whether the UE requires Msg3 with a larger size. Since it would be inefficient to schedule all Msg3 messages with a larger size, there may be a need to define RACH preamble groups or use group B preambles. For UMTS, the RRC CONNECTION SETUP message cannot be extended to carry NAS PDU data, unless advanced features like Common E-DCH are implemented. RRC Connection Setup message is

		transmitted in TM which means that there is no redundancy or segmentation at RLC level. The size of the RRC Connection Setup message should also be considered as it is transmitted in UM which means that there will be no retransmissions at RLC level. A longer message would reduce the probability of successful reception in the UE.
Impact on Mobility		No impact to the mobility. Handover and cell reselection in idle mode are supported.
AS Security impacts		AS security is activated during the RRC Connection Setup procedure. AS SMC may be compromised (New information in RRCConnSetup message (DRB config, SMC) are to be sent using partial encryption. Details of partial encryption are not clear, and whether RRC Connection Setup message needs to be integrity protected is not clear.) Impacts of modified AS level security needs to be analysed by SA3.
Impacts to S1/Iu/X2/Iur signalling		Not much impact expected (if partial encryption is needed, there might be some changes to the S1AP procedure). Does not reduce S1/Iu signalling messages.
Impact to network implementation		Support of new procedures for paging, random access, RRC connection setup, SMC, DRB setup. It is not clear whether the UE indicates its preference to the network to combine RRC messages or not. How does the UE decide when to combine RRC messages? Is this up to UE implementation (e.g. if path loss is not too large) and/or does the network configure the UE (through SIB broadcast or as part of Attach/TAU procedure)? Network may need to fetch UE context earlier or delay the establishment procedure to enable combining the messages.
Impact to UE implementation		Support of new procedures for paging, random access, RRC connection setup, SMC, DRB setup. The UE needs to decide whether to use RRC message combining based on eNB/RNC capability (and/or path loss).
Impact on UE Power Consumption		From the UE power consumption point of view, there may not be big difference between normal procedure and optimized procedure. Main contributor for the power consumption is the DRX periodicity. Combining several procedures into RRC connection setup may cause combined (and then larger) RRC messages to be sent multiple times due to bad network coverage (unless the UE doesn't use the RRC message combing procedure in bad network coverage). And this may cause UE to unnecessarily consume UE power.
Impact on control plane latency		Reducing the number of RRC messages may decrease the latency on the control plane, but it may also cause several additional HARQ transmissions due larger RRC messages in bad network coverage (unless the UE doesn't use the RRC message combing procedure in bad network coverage). Therefore the impact on control plane latency is not clear. It needs to be checked if the UE can tolerate the delay between RRC Connection Request and RRCConnectionSetup as S1 should be setup in-between
Impact on System/Spectrum efficiency		Might need the introduction of RACH preamble groups or use group B preambles. Increased size of RRC connection request message may result in reduced uplink coverage. Also, combining several procedures into RRC connection setup may cause more frequent connection failure due to increased size of RRC messages (unless the UE doesn't use the RRC message combing procedure in bad network coverage, thus reducing the applicability). Combining RRC messages will result in a larger combined message which might decrease spectral efficiency when sent on SRB0 instead of SRB1 for instance.
Signalling gain	**Radio messages**	This solution reduces the number of RRC messages e.g. due to combining connection setup, AS SMC, DRB setup and measurement configuration.
	Bits over the air	Combining connection setup, AS SMC, DRB setup and measurement configuration into one RRC message could not significantly reduce the number of information bits signalled by RRC (apart from the RLC ACK, RLC/MAC headers, CRC). More bits can be saved for UMTS due to: - No need to transmit UE radio capability in RRC Connection Setup complete - No need to send Initial direct transfer
	S1/Iu interface signalling	This solution does not reduce the number of S1/Iu messages. No gain

5.1.2 Solution 1b. Lean Service Request Procedure

NOTE: This solution is described in TR23.887v0.9.0, section 5.1.1.3.9 "Lean Service Request Procedure".

The proposed solution suggests re-using AS security contexts and activating AS security together with RRC reconfiguration so that RAB setup requires less signalling.

5.1.2.1 RAN aspects

Table 5.1.2.1-1: Qualitative analysis for Solution 1b

Applicability		Applicable for both MT and MO cases. It allows the transmission of a single packet (pair) or multiple (UL/DL) packets
Impacts to radio protocols		1) There is no SMC procedure and new IEs should be added in *RRCConnectionSetupComplete* message (capability indication) 2) AS security is activated when established DRB using *RRCConnectionReconfiguration* message
Impact on Mobility		No impact. Handover and cell reselection in idle mode are supported
AS Security impacts		No SMC procedure. The UE and the eNB establish AS security with the parameters used for the earlier RAB. AS security is activated when established DRB using *RRCConnectionReconfiguration* message. Any further impact needs to be considered by SA3
Impacts to S1/Iu/X2/Iur signalling		Need to add new IE in *Initial UE message*
Impact to network implementation		1) Support of Lean Service Request procedure with capability indication in Service Request message 2) Support of RRC functionality to re-instantiate stored AS security contexts when re-establishing RAB(s) and synchronize usage between UE and eNB
Impact to UE implementation		Same as the impact to network implementation
Impact on UE Power Consumption		No impact
Impact on control plane latency		May reduce the control plane latency because there is no SMC procedure
Impact on System/Spectrum efficiency		No impact
Signaling gain	**Radio messages**	This solution reduces the number of RRC messages since it Skips SMC procedure
	Bits over the air	This solution reduces the number of bits over the air since it Skips the SMC messages
	S1/Iu interface signalling	This solution does not reduce the number of S1/Iu messages. No gain

5.2 Control Plane solutions

5.2.1 Solution 2a. RRC connection without U-plane radio bearer establishment

NOTE: This solution covers the RAN aspects of the solutions described in TR 23.887 v0.9.0, section 5.1.1.3.1 "Use of pre-established NAS security context to transfer the IP packet as NAS signalling without establishing RRC security" and section 5.1.1.3.2 "Optimised handling of C-plane connection for Small Data and Device Trigger Transmission without U-plane bearer establishment in E-UTRAN", which from RAN point of view are very similar. This would also cover the RAN aspects of the solution described in section 5.1.1.3.3 "Small Data Service with T5/Tsp and generic NAS transport", if the possible enhancements to avoid establishing DRB (Data Radio Bearer) and use SRB (Signalling Radio Bearer) for the small data transfer were considered.

The proposed solution aims at optimizing the procedure for transfering a single higher layer message (e.g. a single IP data packet or a SMS) (and possibly its response) starting from RRC idle. The solution consists of piggybacking the IP data packet / SMS (and the response) in control messages, without establishing U-plane radio bearers. For the MO case, the UL packet and possible acknowledgment DL packet are conveyed in RRC Connection Setup Complete/UL Information Transfer and RRC Connection Release/DL Information Transfer messages respectively. For the MT case, the DL packet and possible acknowledgment UL packet are conveyed in DL Information Transfer and UL Information Transfer messages respectively.

5.2.1.1 RAN aspects

Table 5.2.1.1-1: Qualitative analysis for Solution 2a

Applicability	Applicable for both MT and MO in case of LTE. Probably more suited for the transmission of a single packet (pair), but it could also allow the transmission multiple (UL/DL) packets. The entire procedure will need to be repeated for each isolated packet. This solution is then more suitable for infrequent small data transfer. The solution is not described for UMTS. Therefore it is not clear whether the solution works for UMTS or not.
Impacts to radio protocols	Additional IE in RRC Connection Request for 'small data indicator' or "mo-signalling" for small data transmission. Alternatively the 'small data indicator' could be added to the RRC Connection Setup Complete message. Hence, the RRC establishment cause can be set without restriction (i.e., not mo-signalling only). New NAS message in RRC Connection setup complete/RRC Connection Release For MT, new IE to provide "small data flag" in the Paging message. UL Information transfer message needs to include an indication to trigger RRC Connection release. Embedding IP packet either directly or as NAS PDU into RRC message increases the complexity at RRC.
Impact on Mobility	Handover cannot be executed without AS security. Thus, handover is not supported in this solution, unless handover procedure is modified. However, as UE will end up in the IDLE after the whole cycle, no connected mode mobility is expected. Cell reselection in idle mode is supported. It is unclear how radio link failure (or failure to receive higher layer acknowledgement in time) will be handled
AS Security impacts	Data transmission on SRB1 only with NAS security, without AS security activation. This is not seen as an issue. However impacts of missing AS level security need to be analysed by SA3.
Impacts to S1/Iu/X2/Iur signalling	Updates of S1AP messages are expected: 1. S1 Downlink NAS Transfer message includes "release command" to release the RRC Connection. 2. S1 paging includes "small data flag" for the MT case so that UE can start this new procedure. 3. MME needs to know eNB's capability of "infrequent small data" transfer. It could be configured by OAM, or indicated by new "infrequent small data" transfer capability in S1 setup request/eNB configuration update message, or implicitly indicated by the "small data" and "low priority small data" cause value in initial UE message, i.e. if the eNB sends these two new cause value to the MME, the eNB is regarded as support "infrequent small data" transfer. 4. eNB needs to know which MME is optimised for MTC Small Data Transfers. It could be configured by OAM, or by adding "optimized for MTC Small Data Transfers" indication in S1 setup response/MME configuration update message. Impact on dimensioning of the S1-C interface due to additional data traffic. Use of reliable control plane to carry delay tolerant and non-critical data is not efficient. Mixing of user plane data/NAS PDUs and control signalling in the same messages leading to more complexity in the eNB and the MME.
Impact to network implementation	(Although this solution is not completely new, since it's based on TAU procedure) it would lead to increased processing requirements/load at the eNB since ASN.1 encoding/decoding needs to handle a RRC message per each small data packet. "Small data ind" in UL and "small data flag" in DL need to be used by eNB to not establish DRB, AS security, and not configure the UE for measurement reporting. Impact on eNB scheduler to identify and de-prioritise SRB1 of these connections compared SRB1 of other connections. This can be seen necessary if there are a large number of devices generating this type of traffic. At MME new functions need to be supported like extract IP address and TEID from the EPS Bearer ID, decrypt the UL IP packet and form the GTP-U packet, and send it to the S-GW. Encrypt the DL IP packet and form the NAS PDU, and send it to the eNB. Request the eNB to fast release the RRC connection after the NAS transfer.
Impact to UE implementation	UE would need to be able to handle the U-plane msg over C-plane. Also, UE would need to be able to provide/process small data indicator/flag. UE also needs a mechanism to let the AS trigger this procedure at appropriate times.
Impact on UE Power Consumption	From the UE power consumption point of view, there may not be big difference between normal procedure and optimized procedure. Short-lived RRC connection would slightly decrease UE power consumption by removing some message exchange such as AS SMC, DRB setup and measurement configuration, and by releasing the connection immediately after data transfer. However increased processing for the encoding/decoding of RRC messages would go in the other direction (increase UE power consumption)
Impact on control	Short-lived RRC connection would reduce latency for short data transmission by removing some

plane latency		message exchange such as AS SMC, DRB setup and measurement configuration. However, small data traffic may interfere with control signalling on the control plane and lead to increased latency for other control plane messages
Impact on System/Spectrum efficiency		Depending on the amount of small data and frequency of transfer, the solution may interfere CP message transfer as small data are transferred in SRB1. If proper de-prioritisation of this SRB1 is not used, performance of other devices can suffer as resources will be diverted to serve this SRB1 even though it is actually low priority. No Header Compression. No UE capability available: not possible to use optimal radio bearers based on UE capability. From spectrum perspective, signalling has higher redundancy/protection/priority than data. Hence, per bit cost of SRB is higher than DRB. The saving in RRC Connection Reconfiguration and SMC may be insufficient to justify the additional cost due to data over SRB1.
Signalling gain	**Radio messages**	This solution reduces the number of RRC messages e.g. due to omission of AS SMC, DRB setup and measurement configuration.
	Bits over the air	This solution reduces the number of control bits e.g. due to omission of AS SMC, DRB setup and measurement configuration. However limited gains with respect to number of bits over the air are expected, due to the different efficiency to send data over SRB1 rather than DRB
	S1/Iu interface signalling	This solution reduces the number of S1/Iu messages for one UL and DL NAS PDU (2 Initial context setup messages + 2 UE context release)

5.2.2 Solution 2b. Downlink small data transfer using RRC message

NOTE: This solution is described in TR 23.887 v0.9.0, section 5.1.1.3.5 "Downlink small data transfer using RRC message".

Similar to Solution 2a, this proposal suggests a control plane solution for the transfer of single higher layer messages (e.g. a single IP data packet or a SMS), but focuses on the MT case (from the MME to the UE): the DL packet and possible acknowledgment UL packet are conveyed in RRC Connection Setup and RRC Connection Setup Complete messages respectively.

5.2.2.1 RAN aspects

Table 5.2.2.1-1: Qualitative analysis for Solution 2b

Applicability	Applicable only for the MT transmission of a single packet (and its response) for LTE (although the solution could be extended to allow the transmissions of multiple packets, e.g. via DL/UL Information Transfer messages). The entire procedure will need to be repeated for each isolated packet. This solution is then more suitable for infrequent small data transfer.
Impacts to radio protocols	New IEs to provide 'small data flag' in the Paging message. New IE in RRC Connection Setup message to provide the small data. New IE in RRC Connection Setup Complete message to provide the small data ACK.
Impact on Mobility	Handover cannot be executed without AS security. Thus, handover is not supported in this solution, unless handover procedure is modified. However, as UE will end up in the IDLE after the whole cycle, no connected mode mobility is expected. It is unclear how radio link failure (or failure to receive higher layer acknowledgement in time) will be handled
AS Security impacts	Data transmission on SRB1 only with NAS security, without AS security activation. This is not seen as an issue. However impacts of missing AS level security need to be analysed by SA3.
Impacts to S1/Iu/X2/Iur signalling	Update of S1AP messages are expected: S1-AP paging message has to be extended to transfer small data packet Impact on dimensioning of the S1-C interface due to additional data traffic. Use of reliable control plane to carry delay tolerant and non-critical data is not efficient. Mixing of data and control in the same messages leading to more complexity in the eNB and the MME.
Impact to network implementation	Buffering small data in all eNBs that receive it with the page request, then the eNB that receives the page response needs to correlate the page response with the page/buffered small data. New functionality in eNB to correlate the Paging message with the RRC connection request. All eNBs in the TA must store the Paging message and DL packet in anticipation of a Connection request. At eNB, at RRC layer, the ASN.1 encoding/decoding complexity increases to handle NAS PDUs for all small data transfers. S1-AP may need to be scaled-up to accommodate data over control plane From an implementation and deployment perspective, there are open areas due to limited applicability of the solution as well as the agreement that SRB0 cannot be used to transmit DL data in order of KB, due

		to lack of segmentation.
Impact to UE implementation		UE would need to be able to handle the U-plane msg over C-plane. Similar complexity at UE, as foreseen at the eNB w.r.t ASN.1 encoding/decoding complexity.
Impact on UE Power Consumption		From the UE power consumption point of view, there may not be big difference between normal procedure and optimized procedure. Short-lived RRC connection would slightly decrease UE power consumption by removing some message exchange such as AS SMC, DRB setup and measurement configuration, and by releasing the connection immediately after data transfer. However increased processing for the encoding/decoding of RRC messages would go in the other direction (increase UE power consumption)
Impact on control plane latency		Short-lived RRC connection would reduce latency for short data transmission by removing some message exchange such as AS SMC, DRB setup and measurement configuration. However, small data traffic may interfere with control signalling on the control plane and lead to increased latency for other control plane messages
Impact on System/Spectrum efficiency		With this solution, the DL packet (piggybacked into the RRC Connection Setup message) uses SRB0 /RLC TM mode, therefore no segmentation is possible. This would require that the entire IP packet needs to be transmitted in a single subframe. Transmitting a 1 Kbyte packet in one subframe would correspond to a data rate of 8 Mbit/s which is unrealistic. As the small data has to be included in the S1 paging in all TAs where the paging should be delivered, this will increase the S1 traffic. If UE does not response the paging, MME may repeat the paging with small data in all TAs again.
Signalling gain	**Radio messages**	This solution reduces the number of RRC messages e.g. due to omission of AS SMC, DRB setup and measurement configuration.
	Bits over the air	This solution reduces the number of control bits e.g. due to omission of AS SMC, DRB setup and measurement configuration. However limited gains with respect to number of bits over the air are expected, due to the different efficiency to send data over SRB rather than DRB
	S1/Iu interface signalling	This solution reduces the number of S1/Iu messages, because initial UE message and initial context setup can be omitted for MT case.

5.3 S1-MME connectionless approaches

To reduce the amount of signalling caused by idle-connected mode transitions, solutions can be defined where small amounts of data can be transferred while the UE has no NAS signalling connection. Two alternatives are described in TR 23.887. Both alternatives are based on the principle of providing information to the UE about the bearer end-point(s) of the PDN Connection(s) in the SGW. One of the differences is the handling of security.

5.3.1 Solution 3a. Small Data Fast Path

NOTE: This solution is described in TR 23.887 v0.9.0, section 5.1.1.3.6.2 "Small Data Fast Path".

The basic principle of small data fast path solution is to provide information to the UE about the end point of the PDN connection or its bearer(s) in the SGW, such as Bearer Resource ID. The baseline approach over the radio interface is to establish a RRC connection and use DRB for the data transfer when the UE is about to send a small data packet. The data radio bearer can be established using the existing mechanisms for establishing a radio bearer (RRC connection establishment followed by RRC connection reconfiguration), or it can be configured with the RRC connection setup message, hence omitting the RRC reconfiguration procedure. Other alternatives are FFS. For all RRC connections (related to small data fast path transfers) there is no associated S1-MME signalling (apart from the paging message for the MT case). In this solution security is performed between the UE and SGW. Security information is provided by MME to SGW and UE at session creation (details of the security solution are FFS by SA3).

5.3.1.1 RAN aspects

Table 5.3.1.1-1: Qualitative analysis for Solution 3a

Applicability	Applicable for both MT and MO cases. It allows the transmission of a single packet (pair) or multiple (UL/DL) packets The solution is suggested but not described for UMTS.
Impacts to radio protocols	1. “small data indicator” in the RRC Connection Request. 2 “small data indicator” and default DRB configuration in the RRC Connection Setup. 3. DRB should be activated after RRC Connection Setup and before RRC Connection Setup Complete. 4. SGW Bearer Resource ID in the RRC Connection Setup Complete message. 5. If multiple bearers have been activated over default DRB, the UE should append the SGW Bearer Resource ID to each uplink packet. The RRC state is specified as RRC_CONNECTED and NAS state is ECM_IDLE. Modifications may be

		required to support this, maybe as a new state.
Impact on Mobility		RRC CONNECTED mode mobility is not supported as security in the AS layer will not be activated.
AS Security impacts		AS security is not activated. Instead IP and ciphering is activated between UE and SGW, which needs to be specified by SA3.
Impacts to S1/Iu/X2/Iur signalling		Avoids the Initial UE message and signalling for the Initial Context Setup. 1. S1 tunnel is created via GTP-U packet between eNB and SGW which used to be an MME task. 2. For MO the eNB derives the SGW Bearer Resource ID from RRC signalling and establishes a short lived fast path bearer context. 3. For MT, paging needs to be performed first (including a “small data” flag), which results in establishing the fast path tunnel via a dummy UL packet. 4. A fast path specific GTP-U extension header needs to be defined. In addition, if the UE has moved to another cell, the eNB returns an Error Indication to the SGW and S-GW needs to contact MME to page the UE.
Impact to network implementation		All network nodes - eNB, MME, SGW are impacted. 1. eNB handles new RRC messages and parameters. 2. eNB should store default DRB configuration for the UE. 3. eNB should send GTP-U packet directly to the SGW indicated in RRC signalling to create GTP tunnel for small data instead of sending initial UE message to MME. 4. eNB should run a special inactivity timer to remove RRC Connection for this case. 5. SGW should deal with fast path specific GTP-U packet and creates tunnel for the small data. 6. SGW should run a special inactivity timer to remove S1 tunnel.7. SGW has to perform IP and ciphering. Derivation of the S-GW S1-U TEID from the SGW Bearer Resource ID should be available in the eNB. If the eNB receives the SGW Bearer Resource ID and uplink IP packet from the UE, the eNB should be capable of deriving the proper S-GW S1-U TEID, assembling a GTP-U PDU using the received uplink IP packet, adding a GTP-U extension header with the eNB S1-U TEID and forwarding the GTP-U PDU on the S1-U interface to the S-GW. Small data transmission would take place without any UE-associated S1-MME signalling connection being established. Although UE and bearer contexts are established in the eNB, the MME would be neither able to directly address the UE context nor the bearer context in the eNB during small data operation as the UE would appear ECM-IDLE to the MME, i.e. the MME control is limited during “small data fast path” operation.
Impact to UE implementation		Supporting new AS and NAS layer procedures. (i.e., storing the security context for small data transmission and SGW bearer resource ID when the UE switches to idle mode, setting up the DRB in the middle of RRC Connection setup, providing SGW Bearer Resource ID to eNB).
Impact on UE Power Consumption		From the UE power consumption point of view, there may not be big difference between normal procedure and optimized procedure. Main contributor for the power consumption is the DRX periodicity.
Impact on control plane latency		Since there is no S1 messages to MME and associated MME response delays, CP setup can be expected to be faster.
Impact on System/Spectrum efficiency		Spectrum efficiency is impacted because eNB doesn’t have UE radio capability.
Signalling gain	**Radio messages**	This solution reduces a number of RRC messages depending on the final design (but at least the AS security messages).
	Bits over the air	This solution reduces the number of bits over the air since it skips a number of RRC messages, i.e. at least the AS security messages, depending on the final design.
	S1/Iu interface signalling	There is no S1 signalling

5.3.2 Solution 3b. Connectionless Data Transmission

NOTE: This solution is described in TR23.887v0.9.0, section 5.1.1.3.6.3 "Connectionless Data Transmission".

At the first visit of a cell in an eNB (or when the security context for a cell of an eNB is not known/valid), the UE executes a Service Request procedure using the legacy procedures: RRC connection is established over the radio interface together with the associated S1-MME signalling. The UE and the eNB exchange a token provided by the eNB to be used as a future reference to the UE context in the eNB. For subsequent data transmissions in the same cell, the UE can use the connectionless data transmission procedure, i.e. establishing a RRC connection to send the connection ID+token+signature, and using the DRB for data transfer. Other alternatives are FFS. For all RRC connections related to subsequent small data connectionless data transmissions in the same cell there is no further associated S1-MME signalling. In this solution the security model is not changed as the eNB performs the encryption function.

5.3.2.1 RAN aspects

Table 5.3.2.1-1: Qualitative analysis for Solution 3b

Applicability		Applicable for both MT and MO cases. It allows the transmission of a single packet (pair) or multiple (UL/DL) packets. This solution is potentially useful in case of repeated small data transmissions in the same cell (using distinct RRC connections) The solution is suggested but not described for UMTS.
Impacts to radio protocols		1. The TOKEN in the Security Mode Command during the full service request procedure. 2. Connection ID, TOKEN and signature in the RRC Connection Setup Complete message during service request with token. Other alternatives are FFS. The RRC state is specified as RRC_CONNECTED and NAS state is ECM_IDLE, which is not supported configuration at present. Modifications may be required to support this, maybe as a new state.
Impact on Mobility		RRC CONNECTED mode mobility is not required if the connectionless mode lasts for short period. If UE reselects the target cell without token, UE should perform service request procedure where MME should be involved.
AS Security impacts		There would be impact on AS security procedure e.g. for handling token
Impacts to S1/Iu/X2/Iur signalling		Avoids the Initial UE message and signalling for the Initial Context Setup for all subsequent data transmissions in the same cell. 1. The S1 tunnel is created via normal S1-MME signalling 2. Once a specific timer elapses, S1/RRC connection is released but the UE/bearer context is kept in the eNB. 3. The eNB maps a bearer id used on Uu to the S1 tunnel. In addition, if the UE has moved to another cell, the eNB returns an Error Indication to the SGW and S-GW needs to contact MME to paging the UE.
Impact to network implementation		All network nodes - eNB, MME, SGW are impacted. 1. eNB handles new RRC messages and parameters. 2. eNB should store the UE context, mapping between connection ID+token+signature and UE context, mapping between the connection ID and the SGW TEID until the context expires even if the UE switches to idle mode. Derivation of the S-GW S1-U TEID from the SGW Bearer Resource ID should be available in the eNB. If the eNB receives the SGW Bearer Resource ID and uplink IP packet from the UE, the eNB should be capable of deriving the proper S-GW S1-U TEID, assembling a GTP-U PDU using the received uplink IP packet, adding a GTP-U extension header with the eNB S1-U TEID and forwarding the GTP-U PDU on the S1-U interface to the S-GW. Small data transmission would take place without any UE-associated S1-MME signalling connection being established. Although UE and bearer contexts are established in the eNB, the MME would be neither able to directly address the UE context nor the bearer context in the eNB during small data operation as the UE would appear ECM-IDLE to the MME, i.e. the MME control is limited during “connectionless data transmission” operation.
Impact to UE implementation		Supporting new AS and NAS layer procedures. (i.e., storing the security context for small data transmission and SGW bearer resource ID when the UE switches to idle mode, providing SGW Bearer Resource ID to eNB)
Impact on UE Power Consumption		From the UE power consumption point of view, there may not be big difference between normal procedure and optimized procedure. Main contributor for the power consumption is the DRX periodicity.
Impact on control plane latency		Since there is no S1 messages to MME and associated MME response delays, CP setup can be expected to be faster.
Impact on System/Spectrum efficiency		eNB can cache UE radio capability so no special impact on spectrum efficiency is expected if UE capability is cached.
Signalling gain	**Radio messages**	For all subsequent data transmissions in the same cell, this solution reduces the AS security messages.
	Bits over the air	For all subsequent data transmissions in the same cell, this solution reduces the number of bits over the air since it skips the AS security messages.
	S1/Iu interface signalling	For all subsequent data transmissions in the same cell, there is no S1 signalling.

5.3.3 Solution 3c. RACH-based Small Data Transmission

This is similar to the connectionless data transmission (solution 3b) but the small data packet in uplink is transmitted in RRC_Idle state of the UE using the RACH procedure (see Figure 5.3.3-1). In this solution, there is no change to the preamble transmission and RA response (Msg-2) of the existing RACH procedure. In RA message 3 (Msg-3) the UE includes the indication for connectionless transmission along with the S-TMSI and BSR. In response the UE receives the contention resolution message (Msg-4) along with the grant to transmit the small data packet for which BSR was sent in Msg-3. The small data is transmitted on a default data radio bearer (DRB) which is activated at the eNB on reception of Msg-3 and at the UE on reception of Msg-4. The default configuration of DRB is pre-configured at UE and eNB. The default DRB is a common radio bearer between the UE and eNB for all PDN connections for which connectionless transmission is enabled. Therefore, for each UL packet transmitted, the UE includes the gateway identifier (similar to connection ID in solution 3b) and S-TMSI. The default DRB configuration remains activated till the timers at UE and eNB are running and there is no need to execute preamble transmission and Msg-2 exchange if there is subsequent small data packet to be transmitted.

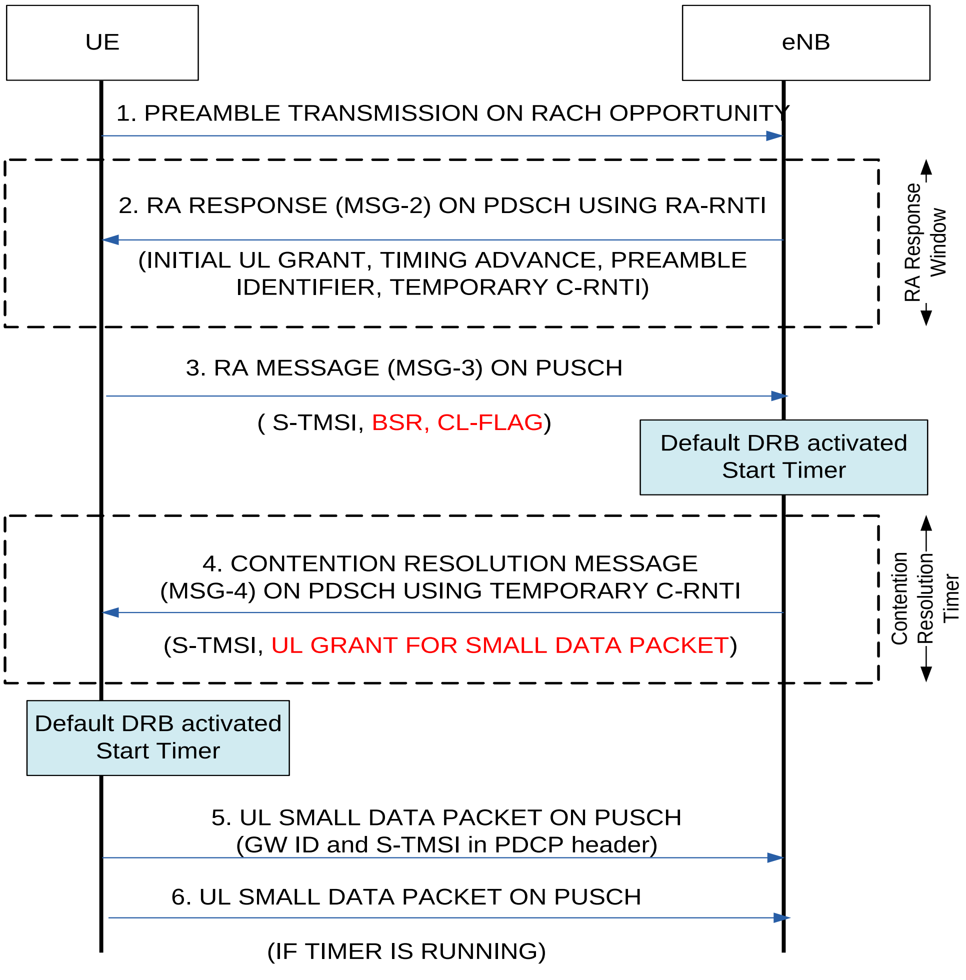

Figure 5.3.3-1: Solution 3c RACH based Small Data Transmission.

The security functionality is retained between the UE and the eNB and handled at the PDCP layer. A separate connectionless security context is used by the UE and eNB when the connectionless transmission mode is enabled. The connectionless security materials such as Alg-ID, MME nonce, eKSI, etc. are provided to the UE during initial attach procedure with an associated life time. The UE uses the connectionless security context and derives the security key (K_{CLT}) for encrypting the small data packet. Along with the encrypted small data packet the UE passes the eKSI for the first UL transmission. The eNB requests the MME to derive and pass the security key (K_{CLT}) for the small data protection by providing the eKSI. When the UE is in idle mode, it uses the established context for the further small data transmissions in the same cell and till the life time of the key. When the UE moves to connected mode, the connectionless security context for the small data traffic is deleted and the UE may follow the existing procedure for establishing the AS security context.

During connectionless transmission mode, if the lifetime of security key expires or there is a cell change or PDCP COUNT is about to wrap around, then the security key is refreshed (for details refer to section 5.7.4.5 of TR 33.868). For key refresh, the only information that the UE needs to generate a unique key is MME nonce. The UE initiates the RACH procedure for key refresh and sends the eKSI to eNB. Further steps include eNB-MME exchange on S1-MME where the MME provides the MME nonce to eNB. The way eNB delivers the DL packet, the MME nonce is also delivered in same way on PDSCH.

5.3.3.1 RAN aspects

Table 5.3.3.1-1: Qualitative analysis for Solution 3c

<table>
<tr><td colspan="2">Applicability</td><td>Applicable for both MT and MO cases. It allows the transmission of a single packet (pair) or multiple (UL/DL) packets. This solution is potentially useful in case of repeated small data transmissions in the same cell.
The solution is suggested but not described for UMTS.</td></tr>
<tr><td colspan="2">Impacts to radio protocols</td><td>1. The CL-Flag and BSR included in MSG-3 of RACH procedure. 2. UL grant/DL assignment included in MSG-4 of RACH procedure. 3. GW ID (same as connection ID in solution 3b) and S-TMSI included in PDCP header along with small data packet. The RRC state is specified as RRC_IDLE and NAS state is ECM_IDLE.</td></tr>
<tr><td colspan="2">Impact on Mobility</td><td>RRC CONNECTED mode mobility is not required for the connectionless transmission mode.</td></tr>
<tr><td colspan="2">AS Security impacts</td><td>There would be impact on AS security procedure e.g. new connectionless security context. If UE reselects the target cell or PDCP count is about to wrap around or key lifetime has expired, UE should perform key refresh request where MME should be involved.</td></tr>
<tr><td colspan="2">Impacts to S1/Iu/X2/Iur signalling</td><td>Same as Solution 3b.</td></tr>
<tr><td colspan="2">Impact to network implementation</td><td>All network nodes - eNB, MME, SGW are impacted.
1. eNB handles modified RACH procedure. 2. eNB should store the UE context, connectionless security context of UE, mapping between the GW ID and the SGW TEID. 3. Default DRB pre-configuration is required at eNB.
Derivation of the S-GW S1-U TEID from the GW ID should be available in the eNB.
If the eNB receives the GW ID and uplink IP packet from the UE, the eNB should be capable of deriving the proper S-GW S1-U TEID, assembling a GTP-U PDU using the received uplink IP packet, adding a GTP-U extension header with the eNB S1-U TEID and forwarding the GTP-U PDU on the S1-U interface to the S-GW.</td></tr>
<tr><td colspan="2">Impact to UE implementation</td><td>1. Support of modified RACH procedure. 2. Supporting new AS layer procedures (i.e., storing the connectionless security context for small data transmission and GW ID when the UE switches to idle mode, providing GW ID and S-TMSI to eNB for every UL packet). 3. Default DRB pre-configuration is required at UE.</td></tr>
<tr><td colspan="2">Impact on UE Power Consumption</td><td>From the UE power consumption point of view, there may not be big difference between normal procedure and optimized procedure.</td></tr>
<tr><td colspan="2">Impact on control plane latency</td><td>Since there is no S1 messages to MME and associated MME response delays, CP setup can be expected to be faster.</td></tr>
<tr><td colspan="2">Impact on System/Spectrum efficiency</td><td>UE radio capability can be part of default DRB pre-configuration so no special impact on spectrum efficiency is expected.</td></tr>
<tr><td rowspan="3">Signalling gain</td><td>Radio messages</td><td>This solution does not require any RRC messages to be exchanged between UE and eNB, instead everything is handled by RACH procedure</td></tr>
<tr><td>Bits over the air</td><td>This solution reduces the number of bits over the air since it skips the RRC messages.</td></tr>
<tr><td>S1/Iu interface signalling</td><td>For all subsequent data transmissions in the same cell, there is no S1 signalling.</td></tr>
</table>

5.4 S1/Iu-only optimizations

5.4.1 Solution 4a: Stateless Gateway for cost efficient transmission of infrequent or frequent small data

NOTE: This solution covers aspects with RAN impacts of the solutions described in TR 23.887 v0.9.0, section 5.1.1.3.4 "Stateless Gateway for cost efficient transmission of infrequent or frequent small data".

This solution aims at reducing the signaling between core network nodes, via a stateless gateway.

5.4.1.1 RAN aspects

Table 5.4.1.1-1: Qualitative analysis for Solution 4a

Applicability		Applicable for both MT and MO cases. It allows the transmission of a single packet (pair) or multiple (UL/DL) packets. Applicable to UEs having a single PDN connection and single bearer The solution is not described for UMTS. Therefore it is not clear whether the solution works for UMTS or not.
Impacts to radio protocols		No impact
Impact on Mobility		No impact
AS Security impacts		No impact
Impacts to S1/Iu/X2/Iur signalling		1. eNB provides indication that it supports the new procedure to MME. 2. MME includes “GW-BR-Support” and “CGW state info” in Initial Context Setup. 3. eNB includes “eNB F-TEID”, “CGW state info” in the first UP GTP packet.
Impact to network implementation		New functions in eNB, MME and GW to support the new parameters in the messages The optimisation is completely on the GW side, which does not retain (permanent) UE states, but maintains bearer contexts in a time-based fashion instead of explicitly setting them up or releasing them by the MME. The necessary information is provided by the necessary addition of control plane level information within a GTP-U header extension.
Impact to UE implementation		Solution restricts UE to have a single PDN connection and single bearer
Impact on UE Power Consumption		No impact
Impact on control plane latency		No impact
Impact on System/Spectrum efficiency		This procedure skips the Modify Bearer procedure among core network nodes
Signalling gain	**Radio messages**	No gain
	Bits over the air	No gain
	S1/Iu interface signalling	No gain

5.4.2 Solution 4b: Optimized Service Request procedure for UEs with a single bearer

NOTE: This solution covers aspects with RAN impacts of the solutions described in TR23.887v0.9.0, section 5.1.1.3.8 "Optimized Service Request procedure for UEs with a single bearer".

The proposed solution applies for devices that only have a single PDN connection (e.g., to internet) and a single bearer. For these UEs, this solution reduces network signalling under certain conditions by not invoking the Modify Bearer Request (MBR) or Modify Access Bearers Request (MABR) over the S11 interface.

5.4.2.1 RAN aspects

Table 5.4.2.1-1: Qualitative analysis for Solution 4b

Applicability	Applicable for both MT and MO cases. It allows the transmission of a single packet (pair) or multiple (UL/DL) packets
Impacts to radio protocols	No impact
Impact on Mobility	The source eNB needs to include the SGW support indication that it received from the MME in the Initial Context Setup Request, in the X2 HO information to the target eNB. MME needs to include the SGW support indication in the S1 HO request to the target eNB.
AS Security impacts	No impact

Impacts to S1/Iu/X2/Iur signalling		For LTE: 1. MME needs to know if an eNB support the MBR optimization, via "eNB support indication" in S1AP: Initial UE Message or S1 Setup Request, or configured by OAM. 2. eNB needs to know if the SGW support the optimization, needs to add "SGW support indication" in S1AP: Initial Context Setup Request, X2AP: Handover Request, and S1AP: Handover Request For UMTS: 1. OAM configures "RNC support the MBR optimization" to SGSN 2. OAM configures "SGW support the optimization" to RNC
Impact to network implementation		1) Support GTP-U header extensions (S1-U) to include eNB F-TEID 2) Dummy packets are sent in error cases when a response is not received and in DL case when eNB needs to send GTP-U header information to SGW before the UE sends UL data 3) when sending NAS or HO related messages to MME indicate support of optimized signalling and include the SGW support indication in S1/X2 HO information to target eNB
Impact to UE implementation		No impact
Impact on UE Power Consumption		No impact
Impact on control plane latency		No impact
Impact on System/Spectrum efficiency		No impact
Signaling gain	**Radio messages**	No gain
	Bits over the air	No gain
	S1/Iu interface signalling	No gain (This procedure skips the Modify Bearer procedure among core network nodes)

5.5 Keep the UE in connected mode

5.5.1 Solution 5a. Core Network assisted eNB parameters tuning for small data transfer

NOTE: This solution is described in TR 23.887 v0.9.0, section 5.1.2.3.1 "Core Network assisted eNB parameters tuning for small data transfer".

In order to minimize UE state transitions, UEs can be kept in connected mode. The setting of some key parameters like the RRC inactivity timer and the DRX timers could be assisted by the Core Network. This could be based on initial values for the parameters provided at attach time or subscription data (e.g. related to expected mobility pattern, or expected allowed applications characteristics such as whether only mobile originated services are expected by the particular application) and/or the learning of the signalling traffic pattern and/or the mobility pattern of the user. The CN assistance information can enable the RAN to adjust/optimize the RAN parameters applied to the UE and thus reduce the frequency of transitions between idle and connected states, minimize network signalling, and save UE battery consumption.

5.5.1.1 RAN aspects

Table 5.5.1.1-1: Qualitative analysis for Solution 5a

Applicability	Applicable for both MT and MO cases. It allows the transmission of a single packet (pair) or multiple (UL/DL) packets The solution is not described for UMTS. Therefore it is not clear whether the solution works for UMTS or not.
Impacts to radio protocols	No impact
Impact on Mobility	No impact
AS Security impacts	No impact
Impacts to	1. Add "RAN assistance data" in S1AP: UE Context Release Complete, Initial Context Setup Request,

S1/Iu/X2/Iur signalling		Handover Required, Handover Request, and X2AP: Handover Request. 2. Add “CN assistance data” in S1AP: Initial Context Setup Request
Impact to network implementation		Impacts to MME: - setting of CN assistance information based on subscription data and/or (dynamic) monitoring of the UE activity; - storing RAN assistance information received from the last eNB during the release of the last RRC signalling connection; - passing CN and/or RAN assistance information to the eNB during the setup of a new RRC signalling connection. - passing CN and/or RAN assistance information to new MME in case of the idle mobility events and inter MME handovers. Impacts to eNB: - tuning of RAN parameters (e.g. DRX cycle and/or RRC inactivity timer) using CN and/or RAN assistance information; - providing the RAN assistance information to the MME during the release of the RRC signalling connection and S1 and X2 handover procedures. - providing the RAN assistance information to the target eNB over X2 during an X2 handover procedure.
Impact to UE implementation		No impact
Impact on UE Power Consumption		UE power consumption depends on the configuration provided by the eNB.
Impact on control plane latency		No impact
Impact on System/Spectrum efficiency		The MME has to store the information for a huge number of UEs in the coverage. However the MME has to store fair amount of data for the UE anyway and the volume of assistance data per UE is small compared to this. Note 1: In connected mode the assistance information could come from either UE or from core network as proposed in this solution. It would probably be possible to have additional information from the UE (although UE providing assistance info will impact radio interface efficiency and will also need to be implemented by UE). Note 2: (applicable in general for all long term connected mode solutions) If UEs are kept in Connected mode for long times, handover signalling overhead should be reduced for mobiles which are non-stationary. Furthermore, there may be a negative effect on radio resource usage e.g. PUCCH resources if many UEs are kept in connected mode but only active infrequently
Signalling gain	**Radio messages**	No gain (with respect to the solution to keep the UE in Connected mode without this specific proposal). However the gain should be compared to UE going Connected/Idle. Since the entire connection setup procedure may be avoided this has a significant advantage over solutions starting in idle mode. However, handover signalling overhead must be considered for non-stationary devices.
	Bits over the air	As above, the gain should be compared to UE going Connected/Idle.
	S1/Iu interface signalling	As above, the gain should be compared to UE going Connected/Idle.

5.5.2 Solution 5b. Connected mode with UE controlled mobility

For non-stationary UEs, much of the mobility related signalling on the air interface (i.e. measurement reports, handover signalling) can be avoided by using UE controlled mobility. In this solution, the option of using UE controlled mobility in connected mode for UEs with applications generating small and infrequent data transmissions is enabled. With this, the UE can be kept in long term connected mode with minimal overall (connection-establishment plus mobility-related) signalling overhead.

Some necessary optimization needs to be introduced in the current standard to enable UE controlled mobility:

- The UE may re-establish the connection potentially in a different cell; the procedure would succeed as long as the target cell is either prepared (forward preparation) or able to retrieve the UE context (backwards fetch).

- Forward preparation of target cell is part of existing handover preparation procedures. However, this procedure won’t be triggered if there is no handover occurring (e.g. no measurement report in this solution).

- Backwards fetch of UE context needs to be supported between two eNBs. One possibility is the reuse of the RLF indication message (see TS 36.423, section 8.3.9.2); however, this procedure is not supported in existing specifications. The use of RLF indication for this purpose should be further confirmed by RAN3.

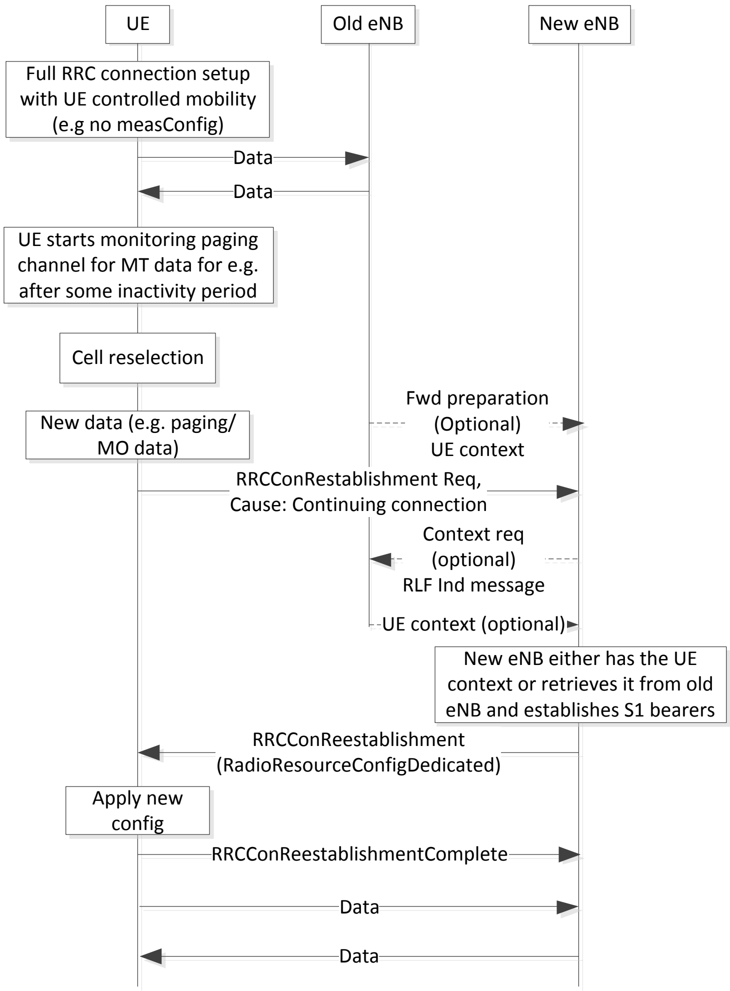

Figure 5.5.2-1: Signalling sequence to resume DRB upon cell reselection

As per section 5.3.7.5 of TS 36.331, during the re-establishment procedure, the UE gets all the necessary information to recalculate the security keys and the nextHopChainingCount value (for subsequent cell changes) in the RRCConnectionReestablishment message. Thus, with this solution, the sending of the security mode command (which is one of the largest signalling messages exchanged during connection setup) is avoided after cell change. It should also be noted that in this case a RRC Reconfiguration message may not be necessary if the DRB is not suspended, unlike in re-establishment procedure due to e.g. RLF or handover failure. This however assumes that a number of changes are necessary for the re-establishment procedure and that these changes need to be supported by both the eNB and the UE, i.e. the re-establishment of SRB2 and DRB through the RRC Connection Reestablishment message.

In case of very infrequent data transmission, the UE may be subjected to more cell reselections than data transmission occasions. In this scenario, it would be beneficial if the UE would attempt the RRC Reestablishment procedure as proposed above only upon a need for new data transmission (i.e. either new MO data or paging). In other words, this would also mean that the UE would be only listening to downlink paging channels for MT data in connected mode (i.e. the network could potentially at this point tear down the S1-U connection). This would also minimise the mean power consumption at the UE (i.e. same as idle mode power consumption).

6 Comparison of solutions for Signalling Overhead Reduction

6.1 Traffic models

The following scenario shall be considered when evaluating the possible signalling overhead reduction allowed by the different proposals:

- Transfer of 100 byte to 1 Kbyte packets in UL and DL with inter-arrival times from several seconds to many hours

In particular the case of one IP packet pair (1 UL + 1 DL) transmitted every [30s, 1min, 5min, 10min, 30min] shall be considered.

Furthermore a simple mobility model is assumed where the UE performs a number of cell changes per minute, in the range from 0 (i.e. stationary UE) to 1 (e.g. 60Km/h with 0.5 Km radius cell).

6.2 Evaluation metrics

Table 6.2-1: Comparison table of solutions for Signalling overhead reduction

Solutions → Evaluation Criterion	Optimized RRC connection management		Control Plane solutions		S1-MME Connection-less approaches		S1/Iu-only optimizations		Keep the UE in connected mode
	Sol 1a	Sol 1b	Sol 2a	Sol 2b	Sol 3a	Sol 3b	Sol 4a	Sol 4b	Sol 5a
Applicability	Applicable for both MT and MO cases. It allows the transmission of a single packet (pair) or multiple (UL/DL) packets.	Applicable for both MT and MO cases. It allows the transmission of a single packet (pair) or multiple (UL/DL) packets.	Applicable for both MT and MO in case of LTE. It could also allow the transmission multiple (UL/DL) packets. More suitable for in frequent small data transfer. The solution is not described for UMTS.	Applicable only for the MT transmission of a single packet (pair) for LTE. More suitable for in frequent small data transfer.	Applicable for both MT and MO cases. It allows the transmission of a single packet (pair) or multiple (UL/DL) packets.	Applicable for both MT and MO cases. It allows the transmission of a single packet (pair) or multiple (UL/DL) packets.	Applicable for both MT and MO cases. It allows the transmission of a single packet (pair) or multiple (UL/DL) packets. Applicable to UEs having a single PDN connection and single bearer. The solution is not described for UMTS.	Applicable for both MT and MO cases. It allows the transmission of a single packet (pair) or multiple (UL/DL) packets.	Applicable for both MT and MO cases. It allows the transmission of a single packet (pair) or multiple (UL/DL) packets The solution is not described for UMTS.
Impacts to radio protocols	There would be significant impact on RRC procedures. For LTE, increasing the size of Msg3 beyond the current limits may impact the MAC layer. There may be a need to define RACH preamble groups or use group B preambles. For UMTS, it would require advanced features like Common E-DCH.	1) There is no SMC procedure and new IEs should be added in *RRCConnectionSetupComplete* message (capability indication) 2) AS security is activated when established DRB using *RRCConnectionReconfiguration* message	Additional IE in several RRC messages. Embedding IP packet either directly or as NAS PDU into RRC message increases the complexity at RRC.	Additional IE in several RRC messages.	Additional IE in several RRC messages. Modifications may be required to support this, maybe as a new state.	Additional IE in several RRC messages. Modifications may be required to support this, maybe as a new state.	No impact	No impact	No impact
Impact on Mobility	No impact. Handover and cell reselection in idle mode are supported.	No impact. Handover and cell reselection in idle mode are supported	Handover is not supported in this solution. However, as UE will end up in the IDLE after the whole cycle, no connected mode mobility is expected. Cell reselection in idle mode is supported.	Handover is not supported in this solution. However, as UE will end up in the IDLE after the whole cycle, no connected mode mobility is expected. Cell reselection in idle mode is supported.	RRC CONNECTED mode mobility is not supported as security in the AS layer will not be activated.	RRC CONNECTED mode mobility is not required if the connectionless mode lasts for short period.	No impact	The source eNB needs to include the SGW support indication that it received from the MME in the Initial Context Setup Request, in the X2 HO information to the target eNB. MME needs to include the SGW support indication in the S1 HO request to the target eNB.	No impact

Solutions → Evaluation Criterion	Optimized RRC connection management		Control Plane solutions		S1-MME Connection-less approaches		S1/Iu-only optimizations		Keep the UE in connected mode
	Sol 1a	Sol 1b	Sol 2a	Sol 2b	Sol 3a	Sol 3b	Sol 4a	Sol 4b	Sol 5a
AS Security impacts	AS security is activated during the RRC Connection Setup procedure. AS SMC may be compromised Impacts of modified AS level security needs to be analysed by SA3.	No SMC procedure. The UE and the eNB establish AS security with the parameters used for the earlier RAB. Any further impact needs to be considered by SA3	Data transmission on SRB1 only with NAS security, without AS security activation. Impacts of missing AS level security need to be analysed by SA3.	Data transmission on SRB1 only with NAS security, without AS security activation. Impacts of missing AS level security need to be analysed by SA3.	AS security is not activated. Instead IP and ciphering is activated between UE and SGW, which needs to be specified by SA3.	There would be impact on AS security procedure e.g. for handling token	No impact	No impact	No impact
Impacts to S1/Iu/X2/Iur signalling	Not much impact expected (if partial encryption is needed, there might be some changes to the S1AP procedure). Does not reduce S1/Iu signalling messages.	Need to add new IE in Initial UE message	Updates of S1AP messages are expected. Impact on dimensioning of the S1-C interface due to additional data traffic. Mixing of user plane data/NAS PDUs and control signalling in the same messages leading to more complexity in the eNB and the MME.	Update of S1AP messages are expected: S1-AP paging message has to be extended to transfer small data packet Impact on dimensioning of the S1-C interface due to additional data traffic. Mixing of data and control in the same messages leading to more complexity in the eNB and the MME.	Avoids the Initial UE message and signalling for the Initial Context Setup. But implies several impacts (see Table 5.3.1.1-1)	Avoids the Initial UE message and signalling for the Initial Context Setup for all subsequent data transmissions in the same cell. But implies several impacts (see Table 5.3.2.1-1)	1. eNB provides indication that it supports the new procedure to MME. 2. MME includes "GW-BR-Support" and "CGW state info" in Initial Context Setup. 3. eNB includes "eNB F-TEID", "CGW state info" in the first UP GTP packet.	For LTE: 1. MME needs to know if an eNB support the MBR optimization, in S1AP: Initial UE Message or S1 Setup Request, or configured by OAM. 2. eNB needs to know if the SGW support the optimization, in S1AP: Initial Context Setup Request, X2AP: Handover Request, and S1AP: Handover Request	1. Add "RAN assistance data" in S1AP: UE Context Release Complete, Initial Context Setup Request, Handover Required, Handover Request, and X2AP: Handover Request. 2. Add "CN assistance data" in S1AP: Initial Context Setup Request
Impact to network implementation	Support of new procedures for paging, random access, RRC connection setup, SMC, DRB setup. Network may need to fetch UE context earlier or delay the establishment procedure to enable combining the messages.	1) Support of Lean Service Request procedure 2) Support of RRC functionality to re-instantiate stored AS security contexts	"Small data ind" in UL and "small data flag" in DL need to be used by eNB to not establish DRB, AS security, and not configure the UE for measurement reporting. Impact on eNB scheduler to identify and de-prioritise SRB1 of these connections compared SRB1 of other connections.	Very limited applicability of the solution as SRB0 cannot be used to transmit DL data in order of KB, due to lack of segmentation . (more impacts in Table 5.2.2.1-1)	All network nodes - eNB, MME, SGW are impacted (see Table 5.3.1.1-1)	All network nodes - eNB, MME, SGW are impacted. (see Table 5.3.2.1-1)	New functions in eNB, MME and GW to support the new parameters in the messages	New functions in eNB, MME and GW to support the new parameters in the messages	Impacts to MME and eNB (see Table 5.5.1.1-1)

Solutions → Evaluation Criterion	Optimized RRC connection management		Control Plane solutions		S1-MME Connection-less approaches		S1/Iu-only optimizations		Keep the UE in connected mode
	Sol 1a	**Sol 1b**	**Sol 2a**	**Sol 2b**	**Sol 3a**	**Sol 3b**	**Sol 4a**	**Sol 4b**	**Sol 5a**
Impact to UE implementation	Support of new procedures for paging, random access, RRC connection setup, SMC, DRB setup. The UE needs to decide whether to use RRC message combining based on eNB/RNC capability (and/or path loss).	Same as the impact to network implementation	UE would need to be able to handle the U-plane msg over C-plane. UE also needs a mechanism to let the AS trigger this procedure at appropriate times.	UE would need to be able to handle the U-plane msg over C-plane. Similar complexity at UE, as foreseen at the eNB	Supporting new AS and NAS layer procedures.	Supporting new AS and NAS layer procedures.	Solution restricts UE to have a single PDN connection and single bearer	No impact	No impact
Impact on UE Power Consumption	There may not be big difference between normal procedure and optimized procedure.	No impact	There may not be big difference between normal procedure and optimized procedure.	There may not be big difference between normal procedure and optimized procedure.	There may not be big difference between normal procedure and optimized procedure.	There may not be big difference between normal procedure and optimized procedure.	No impact	No impact	UE power consumption depends on the configuration provided by the eNB.
Impact on control plane latency	Reducing the number of RRC messages may decrease the latency on the control plane, but it may also cause several additional HARQ transmissions due larger RRC messages in bad network coverage (unless the UE doesn't use the RRC message combing procedure in bad network coverage).	May reduce the control plane latency because there is no SMC procedure	Short-lived RRC connection would reduce latency for short data transmission by removing some message exchange such as AS SMC, DRB setup and measurement configuration	Short-lived RRC connection would reduce latency for short data transmission by removing some message exchange such as AS SMC, DRB setup and measurement configuration	Since there is no S1 messages to MME and associated MME response delays, CP setup can be expected to be faster.	Since there is no S1 messages to MME and associated MME response delays, CP setup can be expected to be faster.	No impact	No impact	No impact

Solutions → Evaluation Criterion	Optimized RRC connection management		Control Plane solutions		S1-MME Connection-less approaches		S1/Iu-only optimizations		Keep the UE in connected mode
	Sol 1a	Sol 1b	Sol 2a	Sol 2b	Sol 3a	Sol 3b	Sol 4a	Sol 4b	Sol 5a
Impact on System/ Spectrum efficiency	Might need the introduction of RACH preamble groups or use group B preambles. Increased size of RRC connection request message may result in reduced uplink coverage.	No impact	If proper de-prioritisation of this SRB1 is not used, performance of other devices can suffer as resources will be diverted to serve this SRB1 even though it is actually low priority. No Header Compression. No UE capability available.	The DL packet uses SRB0 /RLC TM mode. This would require that the entire IP packet needs to be transmitted in a single subframe. Transmitting a 1 Kbyte packet in one subframe would correspond to a data rate of 8 Mbit/s which is unrealistic.	Spectrum efficiency is impacted because eNB doesn't have UE radio capability.	eNB can cache UE radio capability so no special impact on spectrum efficiency is expected if UE capability is cached.	This procedure skips the Modify Bearer procedure among core network nodes.	No impact	The MME has to store the information for a huge number of UEs in the coverage. However the MME has to store fair amount of data for the UE anyway and the volume of assistance data per UE is small compared to this.

Explanations:

- Applicability: Indicates for which scenarios and traffic patterns a solution is available or not (e.g. if the solution is applicable for both MT and MO cases, if it allows the transmission of a single packet or more, etc.)
- Impacts to radio protocols: Refers to impact to existing radio protocols (e.g. RRC)
- Impact on Mobility: Refers to whether the solution supports mobility, has any limitations related to handover/ cell reselection support and/or whether and how it affects handover/cell reselection performance (e.g. some solutions may be specific to stationary devices)
- AS Security impacts: Refers to whether there is a need to specify new mechanisms.
- Impacts to S1/Iu/X2/Iur signalling: Refers to impacts to S1/Iu signalling
- Impact to network implementation: Refers to the impact on the network (e.g. eNB/RNC) implementation
- Impact to UE implementation: Refers to the impact on UE implementation
- Impact on UE power consumption: Indicates whether the solution decreases (or increases) UE power consumption
- Impact on control plane latency: Refers to the impact on the latency of existing control signalling
- Impact on System/Spectrum Efficiency: Indicates whether the solution might have an impact on the spectrum efficiency (e.g. due the possible lack of knowledge of UE radio capabilities according to some solutions).
- Radio messages: Indicates how many radio messages can be saved (in %, w.r.t. Rel-11 baseline solution).
- Bits over the air: Indicates how many bits can be saved over the radio interface (in %, w.r.t. Rel-11 baseline solution).
- S1/Iu interface signalling: Indicates how many S1/Iu interface messages can be saved (in %, w.r.t. Rel-11 baseline solution)

6.3 Signalling overhead of the different solutions

This section provides an estimate of the signalling overhead (mainly on Uu, but also on S1) of the following SDDTE alternatives:

- Control Plane solution 2a,
- S1-MME Connectionless solutions 3a & 3b and

- Solution 4b "Optimized Service Request procedure for UEs with a single bearer"

The signalling overhead is compared to the legacy solution to move from RRC idle to RRC connected and then back to RRC idle. The different alternatives are also compared to the (opposite) approach to always "keep the UE in connected".

Regarding the different SDDTE proposals, it can be noted that, from a RAN interfaces point of view, solution 4b corresponds to the legacy solution to move from idle to connected and back and thus it's not separately considered.

To determine the signalling overhead of the suggested enhancements to establish/release a RRC connection, the considered use case in the following is the one of a single small UL packet followed by a single small response DL packet. This is the scenario where the different solutions can show the maximum signalling reduction gain with respect to the legacy idle-> connected -> idle approach. In other words, the signalling gain of the different solutions can only be lower in case multiple packets are sent during the same connection.

6.3.1 LTE case

6.3.1.1 Byte estimate for involved messages and IEs

This section contains a byte estimate for the messages and IEs exchanged on the radio interface for the considered alternatives.

Table 6.3.1.1-1. Byte estimate for the involved messages and IEs – LTE case

Direction	Messages (or IEs)	Bytes (DL)	Bytes (UL)
DL	Random Access Response	7	
UL	RRC Connection Request		7
DL	RRC Connection Setup	38	
UL	RRC Connection Setup Complete		16
DL	RRC Connection Reconfiguration (SRB2 & DRB configuration)	58	
DL	RRC Connection Reconfiguration (DRB configuration)	50	
UL	RRC Connection Reconfiguration Complete		10
DL	RRC Connection Release	10	
UL	RRC Connection Reestablishment Request		7
DL	RRC Connection Reestablishment	38	
UL	RRC Connection Reestablishment Complete		10
UL	BSR		2
DL	RLC Status Report	3	
UL	RLC Status Report		3
UL	NAS Service Request		4
DL	Security Mode Command	11	
UL	Security Mode Complete		10
DL	DL Information Transfer	11	
UL	UL Information Transfer		11
DL	DRB Configuration	12	
UL	KSI + EPS Bearer ID (Solution 2a)		2
UL	SGW Bearer ID (Solution 3a)		5
UL	Connection ID + Token (Solution 3b)		5
UL	Measurement Report		19
DL	RRC Connection Reconfiguration (with mobility info)	87	

6.3.1.2 Legacy idle->conn->idle solution (and SDDTE solution 4b)

Table 6.3.1.2-1 and 6.3.1.2-2 show the signalling overhead on the radio interface (in bytes) and the number of messages exchanged over the S1-MME / Iu interface required to transmit one IP packet pair (UL + DL) using the baseline Rel-11 procedure. From a RAN interfaces point of view, the same considerations apply also for Solution 4b "Optimized Service Request procedure for UEs with a single bearer".

Table 6.3.1.2-1. Byte estimate for the baseline solution (and SDDTE solution 4b) – LTE case

Direction	Messages	Bytes (DL)	Bytes (UL)
UL	Preamble		X
DL	Random Access Response	7	
UL	RRC Connection Request		7
DL	RRC Connection Setup	38	
UL	RRC Connection Setup Complete (NAS Service Request) + BSR		22
DL	Security Mode Command + RLC Status Report	14	
UL	Security Mode Complete + BSR		12
DL	RRC Connection Reconfiguration (SRB2 & DRB configuration) + RLC Status Report	61	
UL	RRC Connection Reconfiguration Complete + BSR		12
UL	Data Packet + RLC Status Report		3
DL	Data Packet + RLC Status Report	3	
DL	RRC Connection Release + RLC Status Report	13	
UL	RLC Status Report		3
	Total signaling (Bytes)	**136**	**59**

Table 6.3.1.2-2. Messages exchanged over the S1-MME interface

Direction	Message
eNB -> MME	Initial UE message
eNB <- MME	Initial Context Setup Request
eNB -> MME	Initial Context Setup Response
eNB -> MME	UE Context Release Request
eNB <- MME	UE Context Release Command
eNB -> MME	UE Context Release Complete
Direction	**Total number of messages**
eNB -> MME	**4**
eNB <- MME	**2**

6.3.1.3 Solution 2a. RRC connection without U-plane radio bearer establishment

Table 6.3.1.3-1 and 6.3.1.3-2 show the signalling overhead on the radio interface (in bytes) and the number of messages exchanged over the S1-MME / Iu interface required to transmit one IP packet pair (UL + DL) / SMS (and the response) using the Control Plane solution 2a.

Table 6.3.1.3-1. Byte estimate for solution 2a – LTE case

Direction	Messages	Bytes (DL)	Bytes (UL)
UL	Preamble		X
DL	Random Access Response	7	
UL	RRC Connection Request (Small Data ID)		7
DL	RRC Connection Setup	38	
UL	RRC Connection Setup Complete (KSI, EPS Bearer ID, Data Packet)		19
DL	RRC Connection Release (Data Packet) + RLC Status Report	13	
UL	RLC Status Report		3
	Total signaling (Bytes)	**58**	**29**

Table 6.3.1.3-2. Messages exchanged over the S1-MME interface

Direction	Messages	S1 signaling gain
eNB -> MME	1: Initial UE message	**75%**
eNB <- MME	1: Downlink NAS Transport	**50%**

6.3.1.4 Solution 3a. Small Data Fast Path

Table 6.3.1.4-1 and 6.3.1.4-1 show the signalling overhead on the radio interface (in bytes) and the number of messages exchanged over the S1-MME interface required to transmit one IP packet pair (UL + DL) using the S1-MME Connectionless solution 3a.

Table 6.3.1.4-1. Byte estimate for solution 3a

Direction	Messages	Bytes (DL)	Bytes (UL)
UL	Preamble		x
DL	Random Access Response	7	
UL	RRC Connection Request (Small Data ID)		7
DL	RRC Connection Setup (*)	38	
DL	RRC Connection Setup (DRB default configuration) (**)	50	
UL	RRC Connection Setup Complete (SGW Bearer ID) + BSR		23
DL	RRC Connection Reconfiguration (DRB default configuration) + RLC Status Report (*)	53	
UL	RRC Connection Reconfiguration Complete + BSR (*)		12
UL	Data Packet + RLC Status Report (***)		3
DL	Data Packet + RLC Status Report	3	
DL	RRC Connection Release + RLC Status Report	13	
UL	RLC Status Report		3
	Total signaling (Bytes) **(with no RRC Connection Reconfiguration)**	**114** **73**	**48** **36**

(*) If the RRC Connection Reconfiguration message is used
(**) If the RRC Connection Reconfiguration message is not used
(***) In the signalling flow in Figure A-3 (taken from TR 23.887 [3]) it seems that the UL data packet is piggybacked in the RRC Connection Setup Complete. However this is not supported by the description in [3] and here it is considered to be a mistake (otherwise the solution would look more like a control plane solution, at least w.r.t. the radio interface).

Table 6.3.1.4-2. Messages exchanged over the S1-MME interface

Direction	Messages	S1 signaling gain
eNB -> MME	None	**100%**
eNB <- MME	None (****)	**100%**

(****) for the MT case there would be a paging message.

6.3.1.5 Solution 3b. Connectionless Data Transmission

Table 6.3.1.5-1 and 6.3.1.5-1 show the signalling overhead on the radio interface (in bytes) and the number of messages exchanged over the S1-MME interface required to transmit one IP packet pair (UL + DL) using the S1-MME Connectionless solution 3a "Connectionless Data Transmission".

Table 6.3.1.5-1. Byte estimate for solution 3b – LTE case

Direction	Messages	Bytes (DL)	Bytes (UL)
UL	Preamble		x
DL	Random Access Response	7	
UL	RRC Connection Request (Small Data ID)		7
DL	RRC Connection Setup	38	
UL	RRC Connection Setup Complete (Connection ID, Token) + BSR		23
DL	RRC Connection Reconfiguration (DRB default configuration) + RLC Status Report (*)	53	
UL	RRC Connection Reconfiguration Complete + BSR (*)		12
UL	Data Packet + RLC Status Report		3
DL	Data Packet + RLC Status Report	3	
DL	RRC Connection Release + RLC Status Report	13	
UL	RLC Status Report		3
	Total signaling (Bytes) **(with no RRC Connection Reconfiguration)**	**114** **61**	**48** **36**

(*) If the RRC Connection Reconfiguration message is used. Note that in the signalling flow in Figure A-5 (taken from TR 23.887 [3]) RRC Connection Reconfiguration / Reconfiguration Complete messages are shown. However, as for solution 3a, it seems that these 2 messages could be skipped, and the "DRB Default configuration" could be passed to the UE during the first access to the cell.

Table 6.3.1.5-2. Messages exchanged over the S1-MME interface

Direction	Messages	S1 signaling gain
eNB -> MME	None	**100%**
eNB <- MME	None (**)	**100%**

(**) for the MT case there would be a paging message.

6.3.1.6 Solution 3c. RACH based Small Data Transmission

Table 6.3.1.6-1: Byte estimate for solution 3c

Direction	Messages	Bytes (DL)	Bytes (UL)
UL	Preamble (*)		x
DL	Random Access Response (RAPID + RAR)	7	
UL	RA Message-3 (**) (1 Byte MAC header + 5 Byte S-TMSI + 1 or 2 Byte BSR and 1 Bit CL-Flag)		8 or 9
DL	Contention Resolution Message-4 (1 Byte MAC header + 5 Byte S-TMSI + 1 Byte MAC sub header + 20 Bits grant + 1 Bit default DRB activation)	10	
UL	Data Packet + 5 Byte S-TMSI + 1 Byte GW ID + eKSI (***) 4 Bits + RLC Status Report		9 or 10
DL	Data Packet + RLC Status Report	3	
	Total signaling (Bytes)	**20**	**17 to 19**

(*) Preamble can be selected from Group B such that grant for Msg-3 given in Msg-2 is larger than 56 bits.
(**) BSR can be 1 byte when separate sub header is not required. Normally Msg-3 does not contain BSR and Msg-4 does not contain grant.
(***) eKSI is 4 Bits according to section 9.9.3.21 of TS 24.301. eKSI is transmitted only for the first UL packet or whenever key refresh has to be initiated. During key refresh MME nonce (4 bytes according to section 9.1.2 of TS 33.401) is delivered to UE to derive new key.

6.3.1.7 Handover signalling

The signalling overhead of the solution always keeping UEs in connected mode is due to the involved handover signalling overhead (while the overhead to establish the RRC connection at the very beginning can be neglected). The impact of such handover signalling overhead is then dependent on the UE mobility (for stationary UEs, the impact is zero). The byte estimate for the intra-LTE handover signalling is shown in Table 6.3.1.7-1 below.

Table 6.3.1.7-1. Byte estimate for (intra-LTE) Handover signalling – LTE case

Direction	Messages	Bytes (DL)	Bytes (UL)
UL	BSR		2
UL	Measurement Report		19
DL	RLC Status Report	3	
DL	RRC Connection Reconfiguration (with mobility info)	87	
UL	Preamble		x
DL	Random Access Response	7	
UL	RRC Connection Reconfiguration Complete		10
DL	RLC Status Report	3	
	Total signaling overhead (Bytes)	**100**	**31**

Table 6.3.1.7-2 shows the messages exchanged over the X2 and S1-MME interfaces during the handover procedure.

Table 6.3.1.7-2. Messages exchanged over the X2 / S1-MME interfaces

Interface	Direction	Messages
X2	SeNB -> TeNB	Handover Request
X2	SeNB <- TeNB	Handover Request Ack
X2	SeNB -> TeNB	SN Status Transfer
S1-MME	TeNB->MME	Path Switch Request
S1-MME	TeNB<-MME	Path Switch Request Ack
X2	SeNB <- TeNB	UE Context Release
Interface	**Direction**	**Total number of messages**
X2	SeNB <-> TeNB	**4**
S1-MME	TeNB <-> MME	**2**

6.4 Impact on System Performance

Considering the size of the radio messages for the different alternatives (as described in Section 6.3) and the assumed traffic/mobility model (as described in Section 6.1), the radio signalling overhead for transmitting each IP packet pair (1 UL + 1 DL) can be analytically derived.

Figure 6.4-1 shows the DL radio signalling overhead for the different alternatives.

NOTE 1: (under the assumption that both the UL and DL packet are transmitted in the same cell) the overhead for the legacy RRC connection establishment/release procedure, solution 2a and solution 3a is not affected by the UE mobility.

NOTE 2: Solution 3b is affected by UE mobility because the first transmission in a new cell needs to follow the legacy RRC connection establishment/release procedure. After the initial transmission the required UE context (e.g. the Token) is assumed to be stored as long as required (i.e. up to 30 minutes in the considered scenario)

NOTE 3: for both solutions 3a and 3b, the assumption is that the RRC Connection Reconfiguration message is NOT used.

NOTE 4: for the solution always keeping UEs in connected mode, only the overhead due to handover signalling is considered (the overhead to establish the RRC connection at the very beginning is neglected).

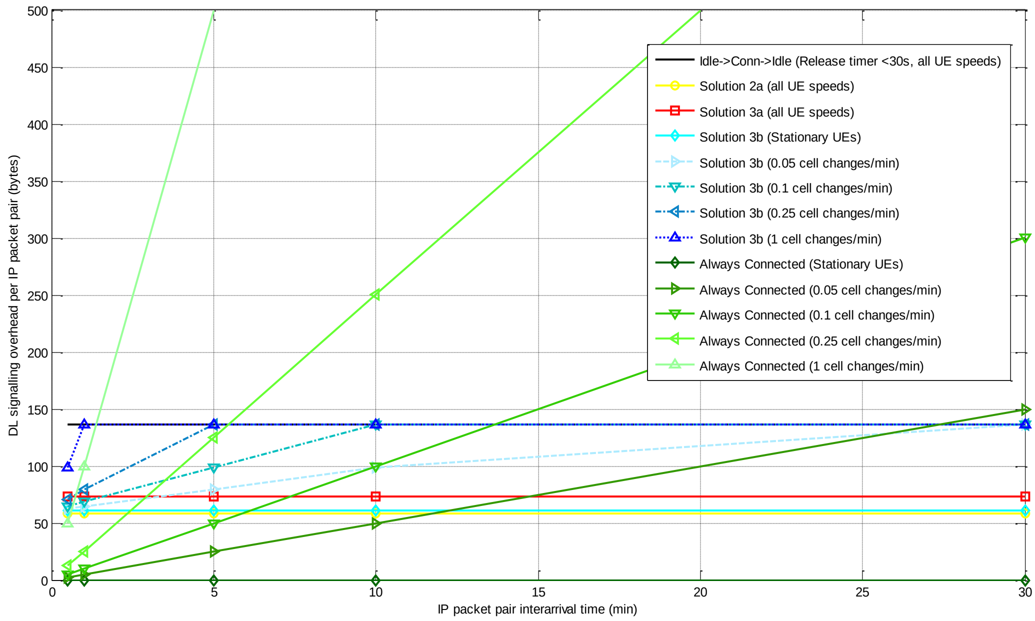

Figure 6.4-1. DL signalling overhead per IP packet pair

Figure 6.4-2 shows the S1-MME / X2 overhead for the different alternatives, considering the number of involved S1-MME / X2 messages.

NOTE 5: More precisely, for the solution always keeping UEs in connected mode only the X2 overhead is considered in the figure, while for all the other solutions only the S1-MME overhead is considered (X2 overhead is zero).

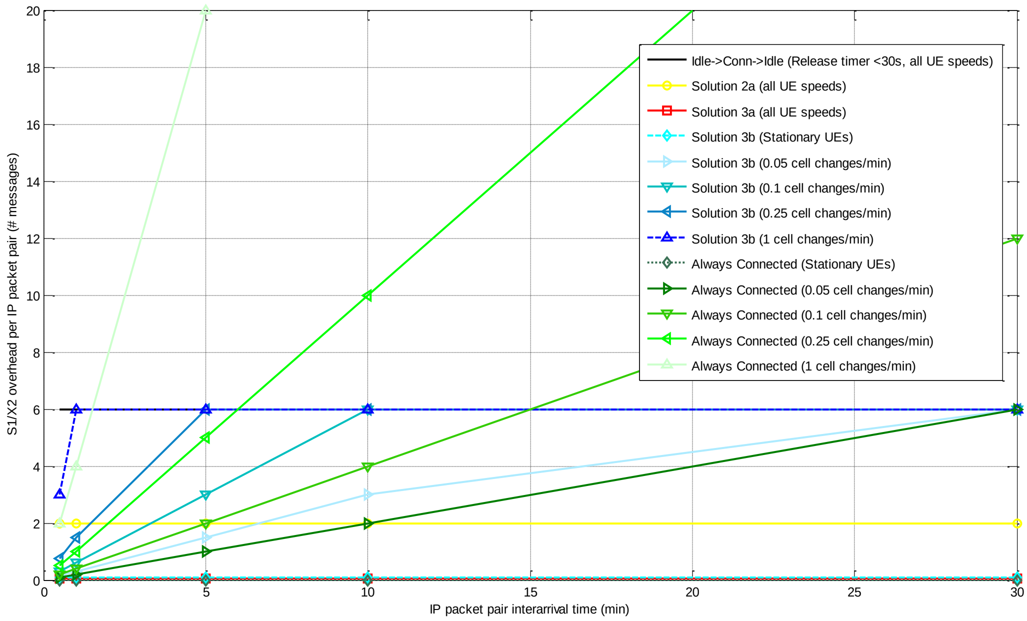

Figure 6.4-2. S1-MME/X2 overhead per IP packet pair

From the signalling overhead evaluation for the different alternatives some straightforward observations can be derived:

Observation 1: Due to the mobility signalling overhead, the solution always keeping UEs in connected mode is not always the best one in terms of radio signalling overhead. For relatively short IP packet inter-arrival times (e.g. shorter than 1 minute) the solution is certainly good, even for moderately high UE speeds (e.g. 1 cell change per minute). For long IP packet inter-arrival times always keeping UEs in connected mode can lead to high signalling overhead, also for low mobility UEs (e.g. with IP packet inter-arrival times longer than 20-25 minutes there would be a signalling overhead increase also for 0.05 cell changes per minute).

Observation 2: When always keeping UEs in connected mode is not viable/efficient (e.g. due to the impact of mobility signalling for fast moving UEs), the (legacy) solution to move from RRC idle to RRC connected and then back to RRC idle can certainly reduce the signalling load.

Observation 3: From a pure signalling overhead point of view, SDDTE solutions for moving from RRC idle to RRC connected and back lead to results which are either better or equal to the legacy solution (for the considered use case, e.g. transmission of isolated IP packet pairs).

Observation 4: For some SDDTE solution the gain (over legacy idle/connected/idle transitions) is independent on the UE mobility and the IP packet pair inter-arrival time, while for other solutions the gain decreases with increasing UE mobility and IP packet pair inter-arrival time.

Considering the message sequences of the different SDDTE solutions, the message size estimates shown in Section 6.3 and some additional assumptions (as in Table 6.4-1 below) it is also possible to estimate the load on the different channels (PDCCH, PDSCH, PUSCH, etc.) for the different proposals.

Table 6.4-1. Evaluation assumptions

Parameters	Value
Packet size (UL and DL)	100 bytes, 1K bytes
Packet inter arrival time	30s, 10min
Cell bandwidth	10MHz (50PRBs)
PDCCH region length	3 OFDM symbols
Average CCEs per PDCCH	4
DL control overhead	30%
UL control overhead	30%
MCS for PDSCH	QPSK, Code rate = 0.1
MCS for PUSCH	QPSK, Code rate = 0.1
PRACH Configuration Index	3
Mobility	From 0 to 1 cell changes per minute

Figures 6.4-3 and 6.4-4 show the load on PDCCH, PDSCH and PUSCH depending on the numbers of UEs in the cell and according to the different alternatives. In Figure 6.4-3 the IP packet pair inter-arrival time is assumed to be 30s, while in Figure 6.4-4 it's 10 minutes. Both the figures show the results for two different packet sizes (in both UL and DL): 100 bytes (left column of the figures) and 1Kbytes (right column of the figures).

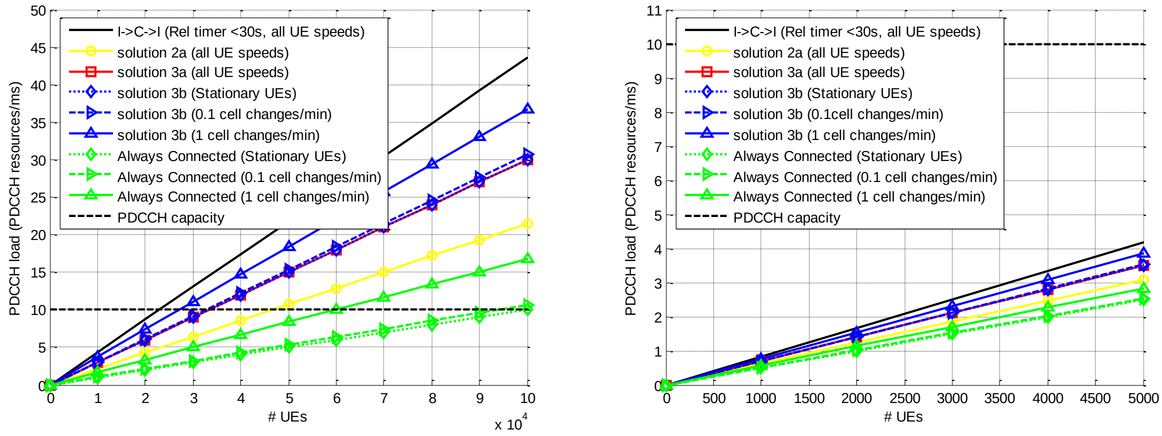

Figure 6.4-3a: PDCCH load. Packet pair IAT = 30s. Left: Pkt size=100bytes, Right: Pkt size=1Kbytes

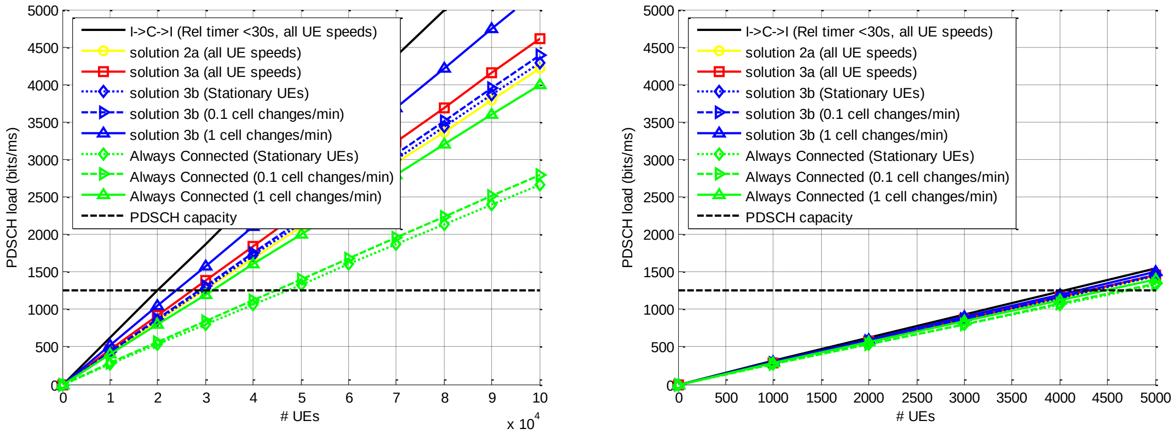

Figure 6.4-3b: PDSCH load. Packet pair IAT = 30s. Left: Pkt size=100bytes, Right: Pkt size=1Kbytes

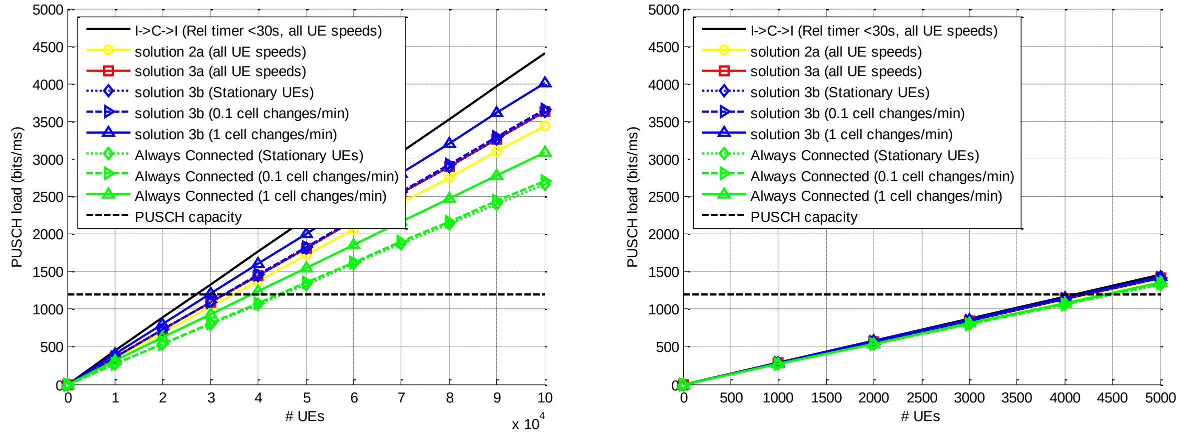

Figure 6.4-3c: PUSCH load. Packet pair IAT = 30s. Left: Pkt size=100bytes, Right: Pkt size=1Kbytes

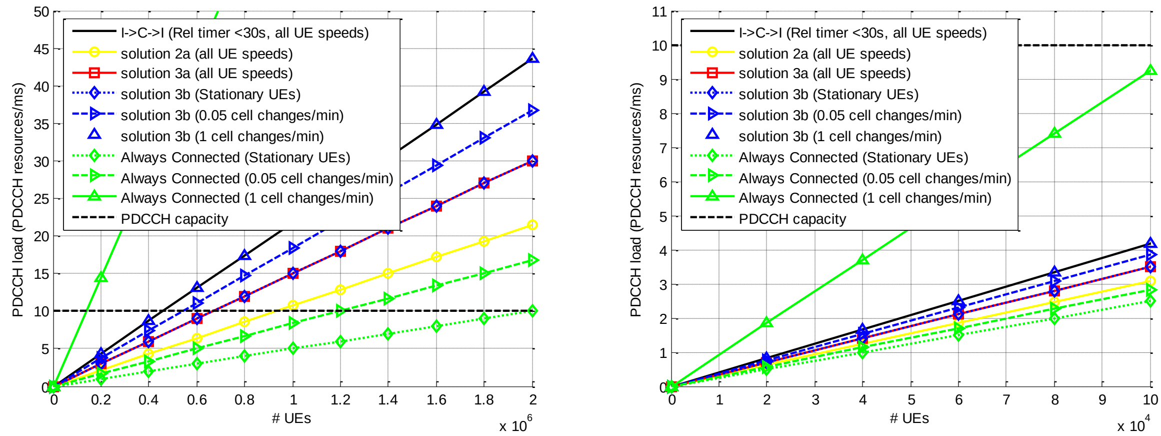

Figure 6.4-4a: PDCCH load. Packet pair IAT = 10min. Left: Pkt size=100bytes, Right: Pkt size=1Kbytes

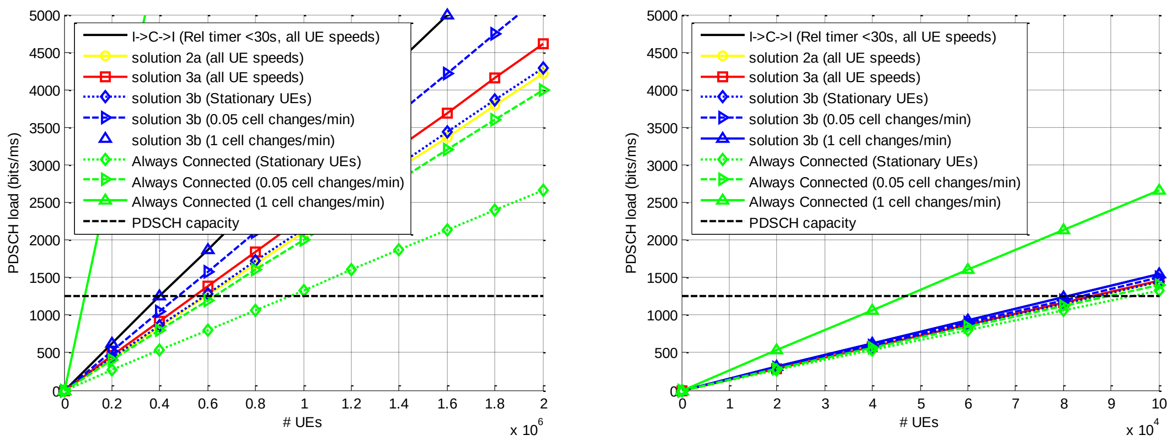

Figure 6.4-4b: PDSCH load. Packet pair IAT = 10min. Left: Pkt size=100bytes, Right: Pkt size=1Kbytes

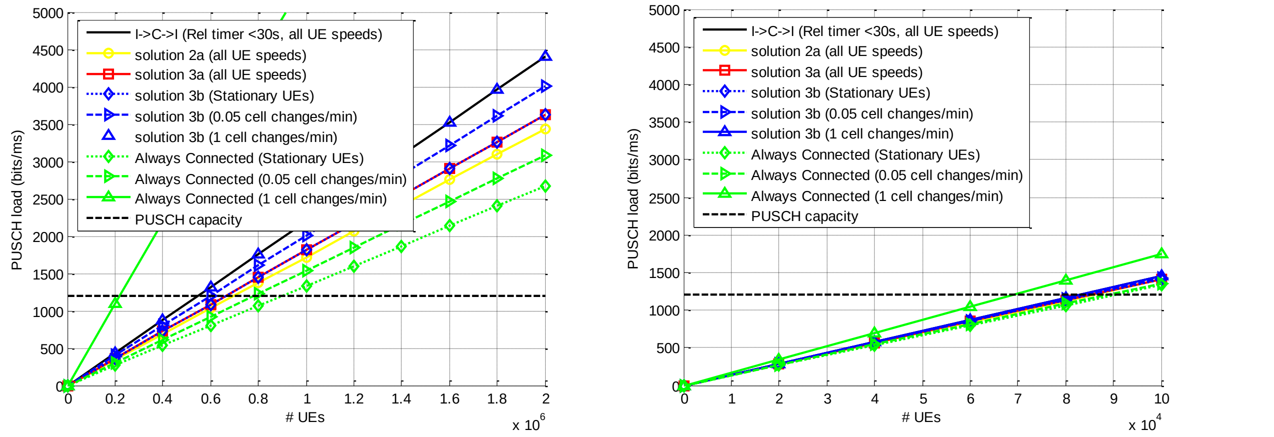

Figure 6.4-4c: PUSCH load. Packet pair IAT = 10min. Left: Pkt size=100bytes, Right: Pkt size=1Kbytes

Some additional observations can be derived:

Observation 5: For large packet sizes (1Kbytes), PDSCH and PUSCH are the limiting factors and the different solutions show quite similar behaviour. So, for large packet sizes, all the SDDTE solutions seem to lead to quite limited benefits on the radio interface (note that, depending on the solutions, there might still be benefits on the S1-MME interface).

Observation 6: For small packet sizes (100 bytes), as already observed from the signalling overhead analysis, SDDTE solutions show some benefits on the radio interface when the packet inter-arrival times and the UE mobility increase. In any case the PDSCH seems still to be the limiting factor (with a packet pair inter-arrival time of 10 minutes, the most efficient SDDTE solution shows a performance gain calculated on the PDSCH curve of nearly 50% compared to the legacy solution to move from idle to connected and then back to idle).

7 Solutions for UE Power Consumption Optimization

7.1 Extended DRX in idle mode

7.1.1 Solution 1a: Extended DRX in idle mode

NOTE: This solution is described in TR 23.887 v0.9.0, section 7.1.3.1 "Extended DRX in idle mode".

The solution proposes to extend the possible DRX cycles in idle mode with longer values to decrease the UE power consumption. When this solution is used, paging transmission period needs to be adjusted based on the extended DRX cycle assigned to the UE in idle mode.

7.1.1.1 RAN aspects

Table 7.1.1.1-1: Qualitative analysis for Solution 1a

Applicability	Idle mode. UEs that can always tolerate traffic with longer access delays for MT services in the order of the maximum extended DRX value. Relatively infrequent data (e.g. several minutes or more).
Impacts to radio protocols	Potential modification to paging (including assuring reliability of Paging Reception) if DRX Cycle is extended beyond 1024 radio frames in LTE or 4096 radio frames in HSPA Updates to RRM requirements may be necessary (RAN4 performance requirements may need to be updated for longer DRX cycles). UE and eNB capability support
Impact on Mobility	Mobility is supported, however cell reselection may be delayed and take longer due to possibly reduced frequency of measurements. Stationary devices may be less impacted by this issue.

Impacts to S1/Iu signalling	Extended DRX Cycle capability support Exchange of extended UE specific DRX value and new paging scheme
Impact to network implementation	Support of protocol extensions to enable negotiation of capability of extended DRX cycles. Potential extension of buffers for pending paging messages Support of extended UE specific DRX values and potential paging enhancement.
Impact to UE implementation	Support of protocol extensions to enable negotiation of capability of extended DRX cycles. Support of extended UE specific DRX values and potential paging enhancement.
Impact on UE Power Consumption	UE Power savings due to longer periods in low power mode.
Impact on UE performance	Longer access delays for MT services.

7.1.2 Solution 1b: Extended DRX using UE Assistance Information

NOTE: This solution is described in TR 23.887 v0.9.0, section 7.1.3.2 "Extended DRX using UE Assistance Information".

The proposed solution suggests that – based on the Power Preference Indication included in the UE assistance information - the network could also decide to extend the DRX cycle / paging cycle in idle mode.

7.1.2.1 RAN aspects

Table 7.1.2.1-1: Qualitative analysis for Solution 1b

Applicability	Idle mode. UEs that can always tolerate traffic with longer access delays for MT services in the order of the maximum extended DRX value. Relatively infrequent data (e.g. several minutes or more)
Impacts to radio protocols	Potential modification to paging (including assuring reliability of Paging Reception) if DRX Cycle is extended beyond 1024 radio frames in LTE or 4096 radio frames in HSPA Updates to RRM requirements may be necessary (RAN4 performance requirements may need to be updated for longer DRX cycles) UE and eNB capability support Add extended DRX Cycle in RRC Connection Release
Impact on Mobility	Mobility is supported, however cell reselection may be delayed and take longer due to possibly reduced frequency of measurements. Stationary devices may be less impacted by this issue.
Impacts to S1/Iu signalling	Extended DRX Cycle capability support Exchange of extended UE specific DRX value and new paging scheme Power Preference Information sent over the S1 interface
Impact to network implementation	Support of protocol extensions to enable negotiation of capability of extended DRX cycles. Potential extension of buffers for pending paging messages New mechanism to handle Power Preference Information Support of extended UE specific DRX values and potential paging enhancement.
Impact to UE implementation	Support of protocol extensions to enable negotiation of capability of extended DRX cycles. Support of extended UE specific DRX values and potential paging enhancement.
Impact on UE Power Consumption	Potential UE Power savings due to longer periods in low power mode.
Impact on UE performance	Longer access delays for MT services.

7.2 Long DRX cycles in connected mode

7.2.1 Solution 2a: Long DRX cycles in connected mode

NOTE: This solution is described in TR 23.887 v0.9.0, section 7.1.3.6 "Long DRX cycles in connected mode".

The proposed solution extends the long DRX cycles in connected mode allowing the terminal to switch off its radio transmitter and receiver for longer periods of time, and thus reduce its power consumption.

7.2.1.1 RAN aspects

Table 7.2.1.1-1: Qualitative analysis for Solution 2a

Applicability	UEs that can always tolerate traffic with longer access delays for MT services as well as DL packet delays in the order of the maximum extended DRX value.
Impacts to radio protocols	Impacts to DRX cycle calculation if DRX cycle is extended beyond 10.24 seconds. Impact to SIB monitoring if UE does not monitor paging according to legacy procedure. Updates to RRM and RLM measurement requirements may be necessary (RAN4 performance requirements may need to be updated for longer DRX cycles).
Impact on Mobility	Without enhancements, mobility performance may be degraded due to increased number of HO failures and RLF occurrences, esp. for high-mobility UE.
Impacts to S1/Iu signalling	
Impact to network implementation	Support of protocol extensions to enable negotiation of capability of extended DRX cycles. Support of extended UE specific DRX values and potential mobility enhancement.
Impact to UE implementation	Support of protocol extensions to enable negotiation of capability of extended DRX cycles. Support of extended UE specific DRX values and potential mobility enhancement.
Impact on UE Power Consumption	UE Power savings due to longer periods in low power mode.
Impact on UE performance	Degradation of service quality for DL packet delivery due to higher UP latency.

7.3 Transmission delay until better coverage conditions

7.3.1 Solution 3a: Transmission delay until better coverage conditions

NOTE: This solution is described in TR 23.887 v0.9.0, section 7.1.3.5 "Transmission delay until better coverage conditions".

This solution allows UEs to transmit at lower power levels by delaying the transmission until coverage conditions are better.

7.3.1.1 RAN aspects

Table 7.3.1.1-1: Qualitative analysis for Solution 3a

Applicability	Delay tolerant traffic
Impacts to radio protocols	None
Impact on Mobility	Mobility is supported.
Impacts to S1/Iu signalling	None
Impact to network implementation	None
Impact to UE implementation	Additional UL Data buffering Received signal quality/strength comparison before packet transmission. New Transmission Delay Timer.
Impact on UE Power Consumption	Potential UE Power savings for mobile UEs.
Impact on UE performance	Potential issue for UEs in cell edge or with high speed. Longer access times for MO services.

No RAN specification impacts are foreseen for this solution.

7.4 Power Saving State

7.4.1 Solution 4a: Power Saving State

NOTE: This solution is described in TR23.887v0.10.1, section 7.1.3.3 "Power Saving State for Devices".

This solution allows the UE to move to a new power saving state, after an active time period starting when the UE moves to idle state. In the power saving state the UE remains attached; however, all AS functionalities stop. The UE is reachable for DL data during the time that the UE is in RRC/S1 connected state and during the active time period (i.e. via paging). The UE wakes up - going back to idle state - when it has UL data pending or when it needs to perform a tracking area update.

Transitions to and from the power saving state are illustrated in Figure 7.4.1-1. When the AS layer is deactivated by the NAS layer, the UE stops all AS procedures. It has not been evaluated whether the UE could directly move to the power saving state from the connected state.

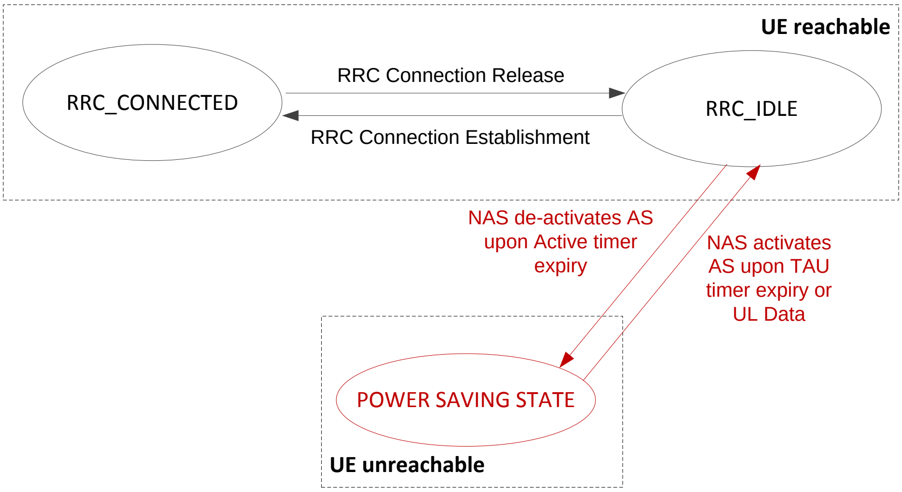

Figure 7.4.1-1: Power saving state in the UE (the figure doesn't imply definition of a new AS state)

7.4.1.1 RAN aspects

Table 7.4.1.1-1: Qualitative analysis for Solution 4a

Applicability	Idle mode. UEs that can always tolerate traffic with longer access delays for MT services in the order of periodic TAU timer value. Relatively infrequent data (e.g. several minutes or more).
Impacts to radio protocols	A new RRC state or a sub-state of RRC IDLE might be needed. Transitions to and from the power saving state are driven by the NAS layer. Need to define procedures executed by the UE in the power saving state, i.e. stop any AS functions.
Impact on Mobility	Mobility is supported but not in power saving state. UE doesn't perform measurement and cell reselection during the power saving state.
Impacts to S1/Iu signalling	S1/Iu signalling is not impacted, because capability negotiation and active time configuration are handled by NAS signalling.
Impact to network implementation	This solution can work without impact to RAN network if the direct transition from connected state to power saving state is not supported. The core network needs to know whether the UE is power saving state capable and sets the active timer to the UE. The core network needs to keep track that the UE moved to the power saving state, e.g. to suppress paging.
Impact to UE implementation	The UE needs to negotiate the use of the power saving state with core network. The new power saving state, as well as the corresponding procedures for transition in and out of power saving state, need to be implemented.
Impact on UE Power Consumption	UE power saving increases due to longer sleep period in power saving state. It has not been evaluated how the frequent periodic TAU (e.g. 1 minute, if configured by the network) might impact UE power saving.
Impact on UE performance	Longer access delays for MT services. This solution limits the UE reachability to the configured durations of the periodic TAU.

8 Comparison of solutions for UE Power Consumption Optimization

8.1 Traffic models

The same scenarios as in section 6.1 shall be considered when evaluating the impact on UE power consumption of the different proposals.

8.2 Evaluation metrics

Table 8.2-1: Comparison table on solutions for UE Power Consumption Optimization

Solutions → Evaluation criterion	Extended DRX in idle mode		Long DRX cycles in connected mode	Transmission delay until better coverage conditions	Power Saving State
	Solution 1a	Solution 1b	Solution 2a	Solution 3a	Solution 4a
Applicability	Idle mode. UEs that can always tolerate traffic with longer access delays for MT services. Relatively infrequent data	Idle mode. UEs that can always tolerate traffic with longer access delays for MT services. Relatively infrequent data	UEs that can always tolerate traffic with longer access delays for MT services as well as DL packet delays.	Delay tolerant traffic	Idle mode. UEs that can always tolerate traffic with longer access delays for MT services in the order of periodic TAU timer value. Relatively infrequent data (e.g. several minutes or more).
Impacts to radio protocols	Potential modification to paging if DRX Cycle is extended beyond 1024 radio frames in LTE or 4096 radio frames in HSPA Updates to RRM requirements may be necessary UE and eNB capability support	Potential modification to paging if DRX Cycle is extended beyond 1024 radio frames in LTE or 4096 radio frames in HSPA Updates to RRM requirements may be necessary UE and eNB capability support Add extended DRX Cycle in RRC Connection Release	Impacts to DRX cycle calculation if DRX cycle is extended beyond 10.24 seconds. Impact to SIB monitoring if UE does not monitor paging according to legacy procedure. Updates to RRM and RLM measurement requirements may be necessary	None	A new RRC state or a sub-state of RRC IDLE might be needed. Transitions to and from the power saving state are driven by the NAS layer. Need to define procedures executed by the UE in the power saving state, i.e. stop any AS functions.
Impact on Mobility	Mobility is supported, however cell reselection may be delayed and take longer due to possibly reduced frequency of measurements. Stationary devices may be less impacted by this issue.	Mobility is supported, however cell reselection may be delayed and take longer due to possibly reduced frequency of measurements. Stationary devices may be less impacted by this issue.	Without enhancements, mobility performance may be degraded due to increased number of HO failures and RLF occurrences, esp. for high-mobility UE.	Mobility is supported.	Mobility is supported but not in power saving state. UE doesn't perform measurement and cell reselection during the power saving state.

Solutions → Evaluation criterion	**Extended DRX in idle mode**		**Long DRX cycles in connected mode**	**Transmission delay until better coverage conditions**	**Power Saving State**
	Solution 1a	**Solution 1b**	**Solution 2a**	**Solution 3a**	**Solution 4a**
Impacts to S1/Iu signalling	Extended DRX Cycle capability support Exchange of extended UE specific DRX value and new paging scheme	Extended DRX Cycle capability support Exchange of extended UE specific DRX value and new paging scheme Power Preference Information sent over the S1 interface	None	None	S1/Iu signalling is not impacted, because capability negotiation and active time configuration are handled by NAS signalling.
Impact to network implementation	Support of protocol extensions to enable negotiation of capability of extended DRX cycles. Potential extension of buffers for pending paging messages Support of extended UE specific DRX values and potential paging enhancement.	Support of protocol extensions to enable negotiation of capability of extended DRX cycles. Potential extension of buffers for pending paging messages New mechanism to handle Power Preference Information Support of extended UE specific DRX values and potential paging enhancement.	Support of protocol extensions to enable negotiation of capability of extended DRX cycles. Support of extended UE specific DRX values and potential mobility enhancement.	None	This solution can work without impact to RAN network if the direct transition from connected state to power saving state is not supported. The core network needs to know whether the UE is power saving state capable and sets the active timer to the UE. The core network needs to keep track that the UE moved to the power saving state, e.g. to suppress paging.
Impact to UE implementation	Support of protocol extensions to enable negotiation of capability of extended DRX cycles. Support of extended UE specific DRX values and potential paging enhancement.	Support of protocol extensions to enable negotiation of capability of extended DRX cycles. Support of extended UE specific DRX values and potential paging enhancement.	Support of protocol extensions to enable negotiation of capability of extended DRX cycles. Support of extended UE specific DRX values and potential mobility enhancement.	Additional UL Data buffering Received signal quality/strength comparison before packet transmission. New Transmission Delay Timer.	The UE needs to negotiate the use of the power saving state with core network. The new power saving state, as well as the corresponding procedures for transition in and out of power saving state, need to be implemented.
Impact on UE Power Consumption	UE Power savings due to longer periods in low power mode.	Potential UE Power savings due to longer periods in low power mode.	UE Power savings due to longer periods in low power mode.	Potential UE Power savings for mobile UEs.	UE power saving increases due to longer sleep period in power saving state. It has not been evaluated how the frequent periodic TAU (e.g. 1 minute, if configured by the network) might impact UE power saving.
Impact on UE performance	Longer access delays for MT services.	Longer access delays for MT services.	Degradation of service quality for DL packet delivery due to higher UP latency.	Potential issue for UEs in cell edge or with high speed. Longer access times for MO services.	Longer access delays for MT services. This solution limits the UE reachability to the configured durations of the periodic TAU.

Explanations:

- Applicability: Indicates for which scenarios and traffic patterns a solution is available or not.
- Impacts to radio protocols: Refers to impact to existing radio protocols (e.g. RRC)
- Impact on Mobility: Refers to whether the solution supports mobility, has any limitations related to handover/ cell reselection support and/or whether and how it affects handover/cell reselection performance (e.g. some solutions may be specific to stationary devices)
- Impacts to S1/Iu signalling: Refers to impacts to S1/Iu signalling
- Impact to network implementation: Refers to the impact on the network (e.g. eNB/RNC) implementation
- Impact to UE implementation: Refers to the impact on UE implementation
- Impact on UE power consumption: Indicates whether the solution can decreases (or increases) UE power consumption
- Impact on UE performance: Indicates whether the solution might have an impact the UE performance (e.g. on paging response, QoS, latency, etc.)

9 Conclusions

On solutions for Signalling Overhead Reduction:

All the solutions for Signalling Overhead Reduction included in Section 5 have been analysed, from a qualitative point of view. This has led to the decision not to further continue the work on a few solutions, e.g. solutions 1a and 2b.

The quantitative aspects (i.e. the corresponding signalling gain) of the remaining solutions have been investigated. This has shown that, in certain conditions, some of the solutions do bring some benefits, in terms of signalling overhead reduction (including on the S1-MME and Iu interfaces) and also in terms of overall system capacity.

Considering that SA2 has finally decided to discontinue the work (in Rel-12) on a number of solutions, including the ‘S1-MME Connectionless’ solutions 3a and 3b, the discussion finally focussed only on solutions 2a and 5a (and only for LTE, not for UMTS).

Regarding solution 2a, the following conclusions can be drawn:

The solution could lead to noticeable performance improvements on both the radio and the S1-MME interfaces only in very specific use cases, specifically only when all the following conditions are fulfilled:

- The solution is used for the transmission of isolated bursts of packets, which means that the transmission of a burst of packets is followed by a relatively long inactivity period (e.g. at least one minute). If the inter-arrival time of the packet bursts is shorter, then this solution would provide worse capacity than legacy solutions as it is more efficient to keep the UEs in RRC connected mode.
- The packet burst is made of maximum 2 packets (in total, i.e. considering both UL and DL packets). If more packets are sent in a burst, the solution would again provide worse capacity than legacy solutions on both the radio and the S1-MME interfaces (as this would require the set up / release of a RRC connection for each packet pair).
- The packets are small in size (e.g. in the order of hundreds of bytes), otherwise (i.e. > 1Kbytes per UL/DL message) the gain over the radio would be lost. And although there would be a reduction in the number of messages on the S1-MME interface, there would be an increase in the size of such S1 messages.

If this solution will be defined, it will be essential to ensure that only traffic matching these characteristics makes use of such a solution, since the use with other traffic patterns would result in capacity and performance loss. So the UE would need means to distinguish such traffic unambiguously.

The impact of handling user plane traffic in the control plane of an eNB (or of handling ciphering and buffering in the MME) has not been studied in depth, but there are some concerns that network nodes were not dimensioned for such kind of use. There is also impact on the eNB for special handling of this SRB1 in terms of prioritisation.

How much overall gain can be achieved with this solution would also largely depend on the share that such traffic (small and rare) has on the overall load. As evaluation has shown, existing solutions can handle several hundred thousands of UEs per cell generating these traffic patterns (if there is no other traffic in the cell).

The alternative defined in clause 5.1.1.3.3 of TR 23.887 has not been specifically discussed. However, if this solution is expected to transfer user data via SRB1 using the RRC Connection Setup Complete and RRC Connection Release messages, the above observations for solution 2a may also apply for the alternative in clause 5.1.1.3.3 of TR 23.887.

Regarding solution 5a, it is believed that the following assistance information could be useful at the eNB (e.g. to determine a suitable RRC connection handling, as well as DRX and UL control channel configuration):

a) UE mobility behaviour. This will be possible in LTE Rel-12, where the UE will be able to provide mobility information upon IDLE=>CONNECTED transitions. The details of the information may be discussed further in the corresponding RAN Work Item (on heterogeneous network mobility enhancements). It was observed that the CN would not know the UE mobility while the UE was IDLE.

b) A description of the traffic type/pattern (e.g. packet inter-arrival time). However it is unclear whether this information could be obtained reliably. It was pointed out that a traffic pattern experienced in the past does not necessarily say too much about the future. For some devices it may be possible to derive information about the traffic pattern, based on e.g. the subscription type and then make use of it (e.g. to configure the RRC connection accordingly or to enable a fast RRC connection release for UEs which transmit very infrequently). For other devices it may not be possible to get any reliable information. It could not be assessed whether such information should come from the CN or directly from the UE. There has also been no quantification of possible gains.

Other solutions such as provisioning of other assistance information (e.g. an indication that the UE is stationary, RRC state transitions counts, connection durations) were not discussed due to lack of time. Therefore, the potential usefulness and feasibility could not be assessed.

On solutions for UE Power Consumption Optimization:

- Solution 4a ('Power saving state') and solution 1a and 2a (introducing very long DRX cycles in IDLE or CONNECTED) are expected to have roughly the same power consumption if the sleep times are equivalent. The transmission of the periodic TAU consumes more power than just waking up and listening for paging, but this is assumed to be negligible if periodic TAU is set to several tens of minutes.

- Differently from the introduction of DRX cycle values beyond 10.24s (for LTE), which would have a number of RAN implications, the definition of a 'Power saving state' has very limited impact on the RAN, if transition into the state is configured/ managed by NAS (however it is unclear how RAN4 would take the power saving state into account).

- The 'Power saving state' solution limits the UE reachability to the configured durations of the periodic TAU (e.g. several tens of minutes) and would then be applicable to some MTC use cases only. The same restriction would apply for solutions introducing DRX cycle values leading to similar sleep times.

- The definition of extended DRX cycles of up to 10.24s (for LTE) will have less impacts on the RAN than very long DRX cycles and could be usable for other use cases than the 'Power saving state'. However, it is still unclear whether extension up to 10.24s may give substantial power saving opportunity or may actually result in increased power consumption due to the need for reading SIB1 before a paging occasion. In any case the extension of DRX cycles would also have impacts regarding mobility related RAN4 performance requirements .

Annex A: Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
2013-04		R2-131355			Initial draft version provided as input to RAN2 #81bis	---	0.0.1
2013-04		R2-131520			Agreed TR skeleton at RAN2#81bis	0.0.1	0.1.0
2013-04		R2-131542			Updated TR including text proposals agreed during RAN2#81bis	0.1.0	0.1.1
2013-04		R2-131544			TR agreed by email after RAN2 #81bis	0.1.1	0.2.0
2013-05		R2-132241			Updated TR including text proposals agreed during RAN2#82	0.2.0	0.2.1
2013-05		R2-132251			TR 37.869 v0.3.0 as agreed by RAN2 in email discussion [82#03] after RAN2 #82	0.2.1	0.3.0
2013-08		R2-133039			Updated TR including text proposals agreed during RAN2#83	0.3.0	0.3.1
2013-08		R2-133046			TR agreed after RAN2 #83	0.3.1	1.0.0